Magnetism Division
Fachverband Magnetismus (MA)

Manfred Fiebig
Department of Materials, ETH Zurich
Vladimir-Prelog-Weg 4
8093 Zurich, Switzerland
manfred.fiebig@mat.ethz.ch

Overview of Invited Talks and Sessions

(Lecture rooms H 0110, H 0112, H 1012, EB 202, EB 301, and EB 407; Poster A and C)

MA-organized plenary talks

PLV XI	Thu	8:30– 9:15	H 0105	**Emergent properties and functions of topological magnets** — •Yoshinori Tokura

INNOMAG e.V. Dissertationspreis 2018 / Ph.D. Thesis Prize

MA 14.1	Mon	15:00–15:25	H 0112	**On the magnetocaloric properties of Heusler compounds** — •Tino Gottschall
MA 14.2	Mon	15:25–15:50	H 0112	**Topological Magnon Materials and Transverse Magnon Transport** — •Alexander Mook
MA 14.3	Mon	15:50–16:15	H 0112	**Ferromagnet-Free Magnetoelectric Thin Film Elements** — •Tobias Kosub
MA 14.4	Mon	16:15–16:40	H 0112	**Optically induced ferro- and antiferromagnetic dynamics in the rare-earth metal dysprosium** — •Nele Thielemann-Kühn

INNOMAG e.V. Diploma-/Master Prize 2018

MA 15.1	Mon	16:55–17:15	H 0112	**Magnetic particle mapping with magnetoelectric sensors for characterization of bioscaffolds** — •Ron-Marco Friedrich
MA 15.2	Mon	17:15–17:35	H 0112	**Uncovering Chiral and Topological Orbital Magnetism of Domain Walls and Skyrmions** — •Fabian R. Lux
MA 15.3	Mon	17:35–17:55	H 0112	**Unified description of high frequency magnetodynamics, and a new way of measuring the magnon contribution to the specific heat.** — •Benjamin Zingsem

Topical talks

MA 10.1	Mon	15:00–15:30	EB 301	**Structure, Energetics, and Deterministic Writing of Skyrmions in Thin Film Ferromagnets** — •Felix Büttner
MA 19.8	Tue	11:30–12:00	EB 301	**Composite topological excitations in ferromagnet-superconductor heterostructures** — •Kjetil Hals
MA 31.1	Wed	15:00–15:30	H 0110	**Magnonics, Quo Vadis?** — •Volodymyr Kruglyak
MA 38.1	Thu	9:30–10:00	H 0110	**RKKY-induced Kondo breakdown near a magnetic quantum phase transiton** — •Johann Kroha
MA 46.1	Thu	15:00–15:30	H 0110	**Topological spin textures as spin-wave emitters** — •Sebastian Wintz

PhD Symposium: Ultrafast spin-lattice interactions

MA 17.1	Tue	9:35–10:20	H 1012	**Understanding spin and lattice interactions at ultrafast timescales** — •Peter M. Oppeneer
MA 17.2	Tue	10:25–10:40	H 1012	**Magnetic and Structural Dynamics in Antiferromagnetically Coupled Fe/Cr Superlattices** — •Daniel Schick
MA 17.3	Tue	10:40–11:10	H 1012	**Spin-Lattice coupling in ultrafast magnetization dynamics** — •Bert Koopmans
MA 17.4	Tue	11:25–11:55	H 1012	**The role of spin-lattice interaction in optical control of magnetism** — •Alexey Kimel
MA 17.5	Tue	11:55–12:10	H 1012	**Structural dynamics during laser-induced ultrafast demagnetization** — •Emmanuelle Jal
MA 17.6	Tue	12:15–12:45	H 1012	**Driving magnetization precession by dynamical compressive and shear strain in a low-symmetry metallic film** — •Alexandra M. Kalashnikova
MA 17.7	Tue	12:45–13:15	H 1012	**Ultrafast Thermal Transport in Magnetic Heterostructures** — •Richard Wilson

Focus sessions (invited talks only)

Nanomagnetism in the x-ray spotlight

MA 2.1	Mon	9:30–10:00	H 1012	**Advanced X-ray Optics - Zone Plates, Kinoforms and Computer Generated Holograms** — •Kahraman Keskinbora
MA 2.2	Mon	10:00–10:30	H 1012	**Time-resolved imaging of nanoscale spin textures and spin waves** — •Jörg Raabe
MA 2.3	Mon	10:30–11:00	H 1012	**Direct observation of magnetic droplet solitons** — •Martina Ahlberg
MA 2.4	Mon	11:15–11:45	H 1012	**Studying nanomagnets by XMCD PEEM** — •Florian Kronast
MA 2.5	Mon	11:45–12:15	H 1012	**A time-resolved view on magnetic domains and spin textures by x-ray holography** — •Stefan Eisebitt

Magnetism in Materials Science: Thermodynamics, Kinetics and Defects I

MA 7.1	Mon	10:15–10:45	TC 010	**First principles many-body calculations for rare earth-based materials: present status and open challenges** — •Silke Biermann
MA 7.5	Mon	11:45–12:15	TC 010	**We need perfect defects - challenging the Brown's paradox in permanent magnetism** — •Oliver Gutfleisch
MA 7.6	Mon	12:15–12:45	TC 010	**Interplay of moment-volume and electron-phonon coupling in the itinerant electron metamagnet $LaFe_{13-x}Si_xH_y$** — •Markus Ernst Gruner

Magnetism in Materials Science: Thermodynamics, Kinetics and Defects II

MA 13.1	Mon	15:45–16:15	TC 010	**Ferromagnetic Nuclear Resonance for studying defects in multilayers and nanocomposites : Structure and magnetic properties** — •Christian Mény
MA 13.5	Mon	17:30–18:00	TC 010	**Improving the finite-temperature description of magnetic materials** — •Anders Bergman

Magnetism in Materials Science: Thermodynamics, Kinetics and Defects III

MA 22.1	Tue	11:45–12:15	H 0106	**Grain boundary migration and grain growth in non-ferromagnetic metals under the impact of a magnetic field** — •Dmitri A. Molodov

Magnetic structurally and compositionally modulated nanowires and nanotubes

MA 8.1	Mon	15:00–15:30	H 1012	**Multiple nanostructures based on anodized aluminium oxide templates** — •Yong Lei

MA 8.3	Mon	15:45–16:15	H 1012	**Towards a three dimensional curvilinear magnonic transducer** — •Jorge A Otalora
MA 8.4	Mon	16:15–16:45	H 1012	**Controlled domain wall propagation in cylindrical nanowires** — •Cristina Bran
MA 8.5	Mon	17:00–17:30	H 1012	**Magnetic hardening of nanowires by sandwiching with antiferromagets** — •Ulf Wiedwald
MA 8.7	Mon	17:45–18:15	H 1012	**Hybrid Magnetoelectric Nanowires for Nanorobotic Applications** — •Salvador Pané

Exploiting spintronics for unconventional computing

MA 24.1	Wed	9:30–10:00	H 1012	**Control of Mesoscopic Magnetism for Computation** — •Laura Heyderman
MA 24.3	Wed	10:15–10:45	H 1012	**Spin waves for unconventional computing and data processing** — •Philipp Pirro
MA 24.4	Wed	11:00–11:30	H 1012	**p-bits, p-transistors and p-circuits** — •Kerem Camsari
MA 24.6	Wed	11:45–12:15	H 1012	**Bits and Brains: New materials and brain-inspired concepts for low energy information processing** — •Theo Rasing

Topological Defects in Superconductors and Magnets

MA 30.1	Wed	15:00–15:30	H 0104	**Stability and Emergent Electrodynamics of Skyrmions** — •Christian Pfleiderer
MA 30.2	Wed	15:30–16:00	H 0104	**Optical Manipulation of Single Flux Quanta** — •Philippe Tamarat
MA 30.3	Wed	16:00–16:30	H 0104	**Skyrmion Lattices in Random and Ordered Potential Landscapes** — •Charles Reichhardt
MA 30.4	Wed	16:45–17:15	H 0104	**Hedgehog Spin-Vortex Crystal Magnetic Order in Superconducting $CaK(Fe_{1-x}M_x)_4As_4$ (M=Co, Ni)** — •Anna Böhmer
MA 30.5	Wed	17:15–17:45	H 0104	**Geometric Frustration and Ratchet Effect of Vortices in an Artificial-Spin/Superconductor Hybrid** — •Zhi-Li Xiao

Spinorbitronics – from efficient charge/spin conversion based on spin-orbit coupling to chiral magnetic skyrmions I

MA 40.1	Thu	9:30–10:00	H 1012	**Understanding Spin-Charge Conversion in Topological Insulators** — •Aurelien Manchon
MA 40.5	Thu	11:15–11:45	H 1012	**Interfacial spin-orbitronic: Rashba interfaces and topological insulators as efficient spin-charge current converters** — •Juan-Carlos Rojas-Sanchez

Spinorbitronics – from efficient charge/spin conversion based on spin-orbit coupling to chiral magnetic skyrmions II

MA 47.1	Thu	15:00–15:30	H 1012	**Spin orbit fields at the Fe/GaAs(001) interface** — •Christian Back

Spinorbitronics – from efficient charge/spin conversion based on spin-orbit coupling to chiral magnetic skyrmions III

MA 57.1	Fri	9:30–10:00	H 1012	**Manipulation of interface-induced Skyrmions studied with STM** — •Kirsten von Bergmann
MA 57.6	Fri	11:30–12:00	H 1012	**Magnonics in skyrmion-hosting chiral magnetic materials** — •Markus Garst

Joint symposia with MA participation

Invited talks of the joint symposium SYTO

See SYTO for the full program of the symposium.

SYTO 1.1	Wed	9:30–10:00	H 0105	**Beyond Topologically Ordered States: Insights from Entanglement** — •B. Andrei Bernevig
SYTO 1.2	Wed	10:00–10:30	H 0105	**Topological Magnon Materials** — Alexander Mook, Jürgen Henk, •Ingrid Mertig
SYTO 1.3	Wed	10:30–11:00	H 0105	**Topological Order of Interacting Polymers on a Substrate** — •Vincenzo Vitelli
SYTO 1.4	Wed	11:15–11:45	H 0105	**Quantization of Heat Flow in Fractional Quantum Hall States** — •Moty Heiblum
SYTO 1.5	Wed	11:45–12:15	H 0105	**Currents and Phases in Quantum Rings** — •Kathryn Moler

Invited talks of the joint symposium SYVC (organized by MA)

See SYVC for the full program of the symposium.

SYVC 1.1	Wed	15:00–15:30	H 0105	**Magneto-ionic control of interfacial magnetism** — •Geoffrey Beach
SYVC 1.2	Wed	15:30–16:00	H 0105	**Ionic Control of Materials Beyond Interfaces** — •Dustin Gilbert
SYVC 1.3	Wed	16:00–16:30	H 0105	**Microscopic Mechanisms of Memristive Switching in Metal Oxides** — •Rainer Waser, Stephan Menzel, Regina Dittmann
SYVC 1.4	Wed	17:00–17:30	H 0105	**In-situ and operando SQUID magnetometry under electrochemical control** — •Roland Würschum, Markus Gössler, Gregor Klinser, Eva-Maria Steyskal, Heinz Krenn
SYVC 1.5	Wed	17:30–18:00	H 0105	**Reversible chemistry as a tool for dynamic control of physical properties** — •Robert Kruk, Subho Dasgupta, Bijoy Das, Horst Hahn

Invited talks of the joint symposium SYTH

See SYTH for the full program of the symposium.

SYTH 1.1	Thu	9:30–10:00	H 0105	**Extracting the electrical properties of metal halide perovskite semiconductors using transient terahertz spectroscopy** — •Michael B. Johnston
SYTH 1.2	Thu	10:00–10:30	H 0105	**THz nanophotonics with 2D materials** — •Miriam SERENA Vitiello
SYTH 1.3	Thu	10:30–11:00	H 0105	**Nonlinear responses and 2D spectroscopy using THz electric and magnetic fields** — •Keith A Nelson
SYTH 1.4	Thu	11:15–11:45	H 0105	**Low energy electrodynamics of correlated spin systems.** — •N. Peter Armitage
SYTH 1.5	Thu	11:45–12:15	H 0105	**Lightwave scanning tunneling microscopy of single molecules** — Dominik Peller, Tyler L. Cocker, Ping Yu, Rupert Huber, •Jascha Repp

Invited talks of the joint symposium SYDM

See SYDM for the full program of the symposium.

SYDM 1.1	Thu	15:00–15:30	H 0105	**Bending, pulling, and cutting wrinkled two-dimensional materials** — •Kirill Bolotin
SYDM 1.2	Thu	15:30–16:00	H 0105	**Ultrafast valley and spin dynamics in single-layer transition metal dichalcogenides** — •Alejandro Molina-Sanchez
SYDM 1.3	Thu	16:00–16:30	H 0105	**Interlayer excitons in layered semiconductor transition metal dichalcogenides** — •Steffen Michaelis de Vasconcellos
SYDM 1.4	Thu	16:45–17:15	H 0105	**Exploring exciton physics in liquid-exfoliated 2D materials** — •Claudia Backes
SYDM 1.5	Thu	17:15–17:45	H 0105	**A Progress Report on Electron Transport in MXenes; A New Family of 2D Materials** — •Michel Barsoum

Invited talks of the joint symposium SYAM

See SYAM for the full program of the symposium.

SYAM 1.1	Fri	9:30–10:00	H 0105	**Bringing Dino-Birds to life – Synchrotron X-ray fluorescence and Raman imaging of ancient materials** — •Uwe Bergmann
SYAM 1.2	Fri	10:00–10:30	H 0105	**Linear and Nonlinear Optical Properties of Cultural Heritage Materials** — •Marta Castillejo
SYAM 1.3	Fri	10:30–11:00	H 0105	**Morphology and topology of multiscale pore networks: Imaging structural alteration and hydric invasion** — •Pierre Levitz
SYAM 1.4	Fri	11:15–11:45	H 0105	**Painting cracks: a way to reveal physical properties of matter** — •Ludovic Pauchard
SYAM 1.5	Fri	11:45–12:15	H 0105	**Finite element analysis and biomechanical interpretation of fossil material properties** — •Emily Rayfield

Sessions

MA 1.1–1.10	Mon	9:30–12:15	H 0112	**Magnetic nanoparticles (joint session MA/CPP)**
MA 2.1–2.7	Mon	9:30–12:45	H 1012	**Focus Session: Nanomagnetism in the x-ray spotlight**
MA 3.1–3.13	Mon	9:30–13:00	H 3010	**Quantum Magnets and Molecular Magnets (joint session TT/MA)**
MA 4.1–4.12	Mon	9:30–12:45	EB 202	**Spin structures and magnetic phase transitions**
MA 5.1–5.14	Mon	9:30–13:15	EB 301	**Heusler compounds, semimetals and oxides (joint session MA/TT)**
MA 6.1–6.12	Mon	9:30–12:45	EB 407	**Ultrafast magnetism I**
MA 7.1–7.8	Mon	10:15–13:15	TC 010	**Focus Session: Magnetism in Materials Science: Thermodynamics, Kinetics and Defects I (joint session MM/MA)**
MA 8.1–8.8	Mon	15:00–18:30	H 1012	**Focus Session: Magnetic structurally and compositionally modulated nanowires and nanotubes**
MA 9.1–9.12	Mon	15:00–18:15	EB 202	**Magnetic domain walls**
MA 10.1–10.12	Mon	15:00–18:30	EB 301	**Skyrmions I (joint session MA/KFM/TT)**
MA 11.1–11.10	Mon	15:00–17:45	EB 407	**Ultrafast magnetism II**
MA 12.1–12.10	Mon	15:00–17:45	HFT-FT 101	**Superconductivity – Topological Defects in Superconductors and Magnets (joint session TT/MA)**
MA 13.1–13.8	Mon	15:45–18:45	TC 010	**Focus Session: Magnetism in Materials Science: Thermodynamics, Kinetics and Defects II (joint session MM/MA)**
MA 14.1–14.4	Mon	15:00–16:55	H 0112	**INNOMAG e.V. Dissertationspreis 2018 / Ph.D. Thesis Prize**
MA 15.1–15.3	Mon	16:55–18:05	H 0112	**INNOMAG e.V. Diploma-/Master Prize 2018**
MA 16.1–16.10	Tue	9:30–12:15	H 0112	**Magnetic characterization techniques**
MA 17.1–17.7	Tue	9:30–13:15	H 1012	**PhD Symposium: Ultrafast spin-lattice interactions (joint session MA/AKjDPG)**
MA 18.1–18.10	Tue	9:30–12:15	EB 202	**Multiferroics and magnetoelectrics I (joint session MA/KFM)**
MA 19.1–19.13	Tue	9:30–13:15	EB 301	**Skyrmions II (joint session MA/TT/KFM)**
MA 20.1–20.12	Tue	9:30–12:45	EB 407	**Magnetocaloric effects (joint session MA/TT)**
MA 21.1–21.114	Tue	9:30–13:00	Poster A	**Poster I**
MA 22.1–22.4	Tue	11:45–13:00	H 0106	**Focus Session: Magnetism in Materials Science: Thermodynamics, Kinetics and Defects III (joint session MM/MA)**
MA 23.1–23.11	Wed	9:30–12:30	H 0112	**Non-ultrafast magnetization dynamics**
MA 24.1–24.6	Wed	9:30–12:15	H 1012	**Focus Session: Exploiting spintronics for unconventional computing (joint session MA/TT)**
MA 25.1–25.9	Wed	9:30–12:00	EB 202	**Multiferroics and magnetoelectrics II (joint session MA/KFM)**
MA 26.1–26.10	Wed	9:30–12:15	EB 301	**Thin films – coupling effects**
MA 27.1–27.12	Wed	9:30–12:45	EB 407	**Spin currents and spin torques**
MA 28.1–28.11	Wed	9:30–12:45	EMH 225	**Multiferroic Oxide Thin Films and Heterostructures I (joint session KFM/TT/MA)**
MA 29.1–29.5	Wed	11:45–13:00	A 053	**Topological Insulators I (joint session TT/MA)**

MA 30.1–30.5	Wed	15:00–17:45	H 0104	**Focus Session: Topological Defects in Superconductors and Magnets (joint session TT/MA)**
MA 31.1–31.11	Wed	15:00–18:15	H 0110	**Magnonics I**
MA 32.1–32.7	Wed	15:00–16:45	H 0112	**Micromagnetism and computational magnetics**
MA 33.1–33.11	Wed	15:00–18:00	H 1012	**Biomedical and molecular magnetism**
MA 34.1–34.8	Wed	15:00–17:00	EB 202	**Spintronics (joint session MA/TT)**
MA 35.1–35.14	Wed	15:00–18:30	EB 301	**Skyrmions III (joint session MA/TT/KFM)**
MA 36.1–36.12	Wed	15:00–18:15	EB 407	**Topological insulators and Weyl semimetals (joint session MA/TT)**
MA 37.1–37.10	Wed	15:00–18:15	EMH 225	**Multiferroic Oxide Thin Films and Heterostructures II (joint session KFM/TT/MA)**
MA 38.1–38.13	Thu	9:30–13:15	H 0110	**Theory of strongly correlated systems**
MA 39.1–39.7	Thu	9:30–11:15	H 0112	**Micro- and nanostructured magnetic materials**
MA 40.1–40.8	Thu	9:30–12:30	H 1012	**Focus Session: Spinorbitronics – from efficient charge/spin conversion based on spin-orbit coupling to chiral magnetic skyrmions I (joint session MA/TT)**
MA 41.1–41.12	Thu	9:30–12:45	EB 202	**Surface magnetism I**
MA 42.1–42.11	Thu	9:30–12:30	EB 301	**Thin films – anisotropy**
MA 43.1–43.10	Thu	9:30–12:15	EB 407	**Magnetic textures I**
MA 44.1–44.13	Thu	9:30–13:00	A 053	**Topological Insulators II (joint session TT/MA)**
MA 45.1–45.11	Thu	9:30–13:30	EMH 225	**Ferroics and Multiferroics (joint session KFM/TT/MA)**
MA 46.1–46.11	Thu	15:00–18:00	H 0110	**Magnonics II**
MA 47.1–47.10	Thu	15:00–18:00	H 1012	**Focus Session: Spinorbitronics – from efficient charge/spin conversion based on spin-orbit coupling to chiral magnetic skyrmions II (joint session MA/TT)**
MA 48.1–48.7	Thu	15:00–17:00	H 2053	**Quantum Coherence and Quantum Information Systems (joint session TT/MA)**
MA 49.1–49.6	Thu	15:00–16:30	EB 202	**Terahertz dynamics**
MA 50.1–50.7	Thu	15:00–16:45	EB 301	**Soft and hard permanent magnets**
MA 51.1–51.9	Thu	15:00–17:30	EB 407	**Magnetic textures II**
MA 52.1–52.73	Thu	15:00–18:00	Poster C	**Poster II**
MA 53	Thu	18:00–19:00	H 0110	**General assembly of the Division of Magnetism (MA)**
MA 54.1–54.8	Fri	8:00–10:00	EB 301	**Spin-dependent transport phenomena**
MA 55.1–55.13	Fri	9:30–13:00	H 0110	**Complex Oxides – Bulk Properties, Surfaces and Interfaces (joint session TT/MA/KFM)**
MA 56.1–56.7	Fri	9:30–11:15	H 0112	**Spin-Hall effects**
MA 57.1–57.9	Fri	9:30–12:45	H 1012	**Focus Session: Spinorbitronics – from efficient charge/spin conversion based on spin-orbit coupling to chiral magnetic skyrmions III (joint session MA/TT)**
MA 58.1–58.6	Fri	9:30–11:00	EB 202	**Surface magnetism II**

General assembly of the Division of Magnetism

Thursday 18.00 – 19.00 H 0110
All members of the Division of Magnetism are invited to attend!

MA 1: Magnetic nanoparticles (joint session MA/CPP)

Time: Monday 9:30–12:15 Location: H 0112

MA 1.1 Mon 9:30 H 0112

Temperature dependence of the magnetic anisotropy of Pt/Co/Pt nanodots — •Stefan Freercks, Eva-Sophie Wilhelm, Carsten Thönnissen, Philipp Staeck, and Hans Peter Oepen — Center for Hybrid Nanostructures, Universität Hamburg, Germay

We use the anomalous Hall-effect to investigate the magnetization reversal of single Pt/Co/Pt nanodots (diameter <35nm, Co thickness< 1.5nm) with perpendicular magnetization. The dots are fabricated by electron beam lithography and ion milling out of thin multilayers[1]. Our technique allows for measuring from room temperature, where the nanodots are usually superparamagnetic, down to low temperatures, where the magnetization is blocked. Measuring the switching times, we find that the attempt frequencies given by the Néel-Arrhenius law are some orders of magnitude higher than the expected GHz regime. Simple considerations show that a temperature dependent anisotropy can very well explain such deviations, which gave the motivation for our investigation. We determined the anisotropy of the initial film and of nanodots as a function of temperature. The anisotropy shows a non-linear temperature dependence in films and dots, which proves our point that temperature effects cannot be neglected in the Néel-Arrhenius law. Furthermore, the temperature dependence varies for different nanodots. The latter variation reveals that generalizations in ensemble measurements have to be handled with care. Funding by DFG via SFB 668 is gratefully acknowledged. [1] A. Neumann et al. Nano Letters. 13, p2199-2203, (2013)

MA 1.2 Mon 9:45 H 0112

Non-coherent reversal of magnetization in single Pt/Co/Pt nanodots with diameter below 100nm — •Eva-Sophie Wilhelm, Stefan Freercks, Philipp Staeck, Carsten Thönnissen, and Hans Peter Oepen — Center for Hybrid Nanostructures, Universität Hamburg, Germany

We investigate magnetization reversal behavior of single Pt/Co/Pt nanodots with a diameter of 35nm and a Co thickness of 1nm using anomalous Hall-effect magnetometry [1] at temperatures from 2.5K to 270K. The samples were fabricated from polycrystalline films by electron beam lithography and ion milling.

For nanodots with uniaxial anisotropy and a diameter below 100nm single domain behavior and coherent rotation reversal according to the Stoner-Wohlfahrt model is expected [2] [3]. However non-coherent switching with two jumps in the hysteresis is observed for some of the dots with out-of-plane magnetization at low temperatures. Comparison of the reversal of two different dots from the same film material and micromagnetic simulation using Mumax3 [4] gives hints that this finding is caused by different local magnetic properties of the initial films. The differences presumably originate from the distribution of grains of different crystal orientation in the nanodots. Funding by DFG via SFB 668 is gratefully acknowledged. [1] A. Neumann et al. Nano Letters. 13, p2199-2203, (2013) [2] A. Neumann, Ph.D thesis, Universität Hamburg, (2015) [3] E. C. Stoner and E. P. Wohlfarth, Philos. Trans. R. Soc. London, Ser. A 240, 599 (1948) [4] A. Vansteenkiste et al. AIP Advances 4 107133 (2014)

MA 1.3 Mon 10:00 H 0112

Chemical and magnetic characterizations of ordered arrangements of magnetic nanoparticles — Asmaa Qdemat[1], Emmanuel Kentzinger[1], •Jin Xu[2], Giuseppe Portale[2], Marina Ganeva[3], Stefan Mattauch[3], Oleg Petracic[1], Ulrich Rücker[1], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science (JCNS) and Peter Grünberg Institute (PGI), JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Herzog-Wilhelm-Allee — [3]Jülich Centre for Neutron Science, Forschungszentrum Jülich, Outstation at MLZ, 85748 Garching, Germany

a.qdemat@fz-juelich.de Keywords: magnetic nanoparticles, grazing incidence small angle scattering, interparticle interactions

Magnetic nanoparticles and their assembly in highly ordered structures are principally interesting regarding the understanding of magnetic interactions and for future applications in information technology as e.g. magnetic data storage media or as material for spintronics.

The work to be presented focuses on the chemical and magnetic characterization of monolayer of CoFe2O4 nanoparticles on silicon substrate. Using Grazing Incidence Small Angle X-ray Scattering (GISAXS) we deduce the height profile of the nanoparticle, and a hexagonal ordering between those nanoparticles. Macroscopic magnetization measurement and polarized neutron reflectometry were used to deduce that the nanoparticles are weakly magnetized with respect to bulk CoFe2O4 and that a random in plane relative orientation of the nanoparticle magnetizations is obtained at zero applied field.

MA 1.4 Mon 10:15 H 0112

Magnetic behavior of single- and polycrystalline nanoparticle superlattices — •Michael Smik[1], Genevieve Wilbs[1], Mauricio Cattaneo[1], Elisa Volkmann[1], Emmanuel Kentzinger[1], Stefan Mattauch[2], Ulrich Rücker[1], Oleg Petracic[1], and Thomas Brückel[1] — [1]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT, 52425 Jülich, GERMANY — [2]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science at MLZ, Lichtenbergstr. 1, 85747 Garching, Germany

Magnetic nanoparticle (NP) assemblies form a novel type of artificial material which hold the promise to display properties that are not found in nature. We have succeeded in fabricating large 3D nanoparticle 'macrocrystals' using a novel centrifuge assisted sedimentation technique from commercially available spherical iron oxide NP. The assembly of polycrystalline samples up to $300\,\mu$m in size was possible, as well as a the realization of a nearly ideal macrocrystal. Using small angle x-ray scattering at our in-house instrument GALAXI the supercrystalline structure and quality of ordering could be characterized. The magnetic properties were investigated by a variety of magnetometric methods. Additional samples of nearly non-interacting NP were prepared to characterize the magnetic behavior of the individual NP. A comparision between the polycrystalline, single crystal and dispersed samples was performed. For a microscopic investigation of the magnetic ordering in the supercrystals, small angle neutron scattering was employed.

MA 1.5 Mon 10:30 H 0112

Structural and magnetic characterization of Pd-decorated cobalt ferrite multifunctional nanoparticles — •Seyedeh Fatemeh Shams[1], Detlef Schmitz[2], Alevtina Smekhova[1], Nataliya Svechkina[1], Konrad Siemensmeyer[2], Amir Hossein Tavabi[3], Rafal E. Dunin-Borkowski[3], and Carolin Schmitz-Antoniak[1] — [1]Peter Grünberg Institute (PGI-6), Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Department for Quantum Phenomena in Novel Materials (EM-IQM), Helmholtz-Zentrum Berlin für Materialien und Energie, 12489 Berlin, Germany — [3]Ernst Ruska Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich, 52425 Jülich, Germany

Pd-decorated CoFe2O4 multifunctional nanoparticles have been synthesized as a hybrid platform for simultaneous magnetic hyperthermia and photothermal therapeutic applications. Elemental and microstructural analyses have been conducted using TEM, HAADF STEM, EDS and ICP-OES. Experimental results confirm successful homogeneous Pd decoration on highly crystalline CoFe2O4 nanoparticles. Cations distributions, which have been inferred from XANES and XRD measurements, suggest the presence of considerable cation disorder, which increases with decreasing particle size for all of the samples. Magnetic properties of the nanoparticles have been investigated using XMCD and magnetometry. Intriguingly high-field XMCD reveals significantly enhanced total magnetic moments for both Fe and Co ions after Pd decoration. This substantially increased magnetization could lead to improved magnetic hyperthermia performance of the nanoparticles.

15 minutes break

MA 1.6 Mon 11:00 H 0112

Distributed heat production in clusters of magnetic nanoparticles — Paola Torche[1], David Serantes[2], Sergiu Ruta[3], Roy Chantrell[3], and •Ondrej Hovorka[1] — [1]University of Southampton, Southampton, UK — [2]Universidade de Santiago de Compostela, Santiago de Compostela, Spain — [3]University of York, York, UK

We address the issue of quantifying the heat produced by a single magnetic nanoparticle (MP) embedded within an interacting MP cluster.

This is relevant for MP hyperthermia considered as a modality for enhancing cancer therapies, where it becomes necessary to understand the distribution of heat production across a MP aggregate inside a living cell. The heat produced by MPs subject to time-varying external magnetic field can be determined from the area of the hysteresis loop. However, at the single-particle level of description, the magnetization of a MP undergoes a fluctuating stochastic process and the meaning of the hysteresis loop becomes ambiguous, as suggested also experimentally. It is then unclear how to quantify the heat production, especially if the interactions between MPs cannot be neglected.

We use the modern stochastic thermodynamics in combination with the Néel-Arrhenius theory of thermal relaxation of MPs to establish the relationship between the fluctuating work and entropy (heat) produced along the fluctuating magnetization trajectories of MPs. By considering the dipolar chains of MPs, we demonstrate a practical recipe for quantifying the heat produced by a single MP embedded within a chain, which then allows to map heat production distributions along the chains.

MA 1.7 Mon 11:15 H 0112

Determination of individual magnetic moments of trapped superparamagnetic particles — •Ulrich Herr, Meng Li, Benjamin Riedmüller, Florian Ostermaier, and Sruthi Sunder — Institute of Micro- and Nanomaterials, Ulm University, Ulm

Superparamagnetic nanoparticles are used in lab-on-chip devices for detection of bio-analytes, drug delivery, or in hyperthermia. Many of these applications would benefit from precise knowledge of the magnetic moment of the individual nanoparticle, which may vary significantly between particles due to the statistical nature of the production process. We have recently demonstrated that individual magnetic particles (Dynabeads M-280 and MyOne T1) can be trapped over long times in a micro-conductor ring combined with an additional homogeneous magnetic field [1], which allows precise determination of a variety of microscopic parameters. Here we demonstrate that capturing more than one particle inside the trap can lead to stable arrangement of the particles inside the magnetic potential landscape of the trap. By measuring the average distance between the nanoparticles in a known trap potential we are able to determine the actual magnetic moment of the trapped nanoparticles, which can not easily be obtained in other ways.

[1] B. Riedmüller, F. Ostermaier, F., U. Herr, Trapping of superparamagnetic particles with a single current-conducting microring, IEEE Transactions on Magnetics 53 (2017) 5300706 DOI: 10.1109/TMAG.2017.2697722

MA 1.8 Mon 11:30 H 0112

Studying the dynamic properties of pure cobalt ferrite nanoparticles and particles coated with silica in PEG-solution by magnetic AC-susceptometry — •Samira Webers[1], Melissa Hermes[2], Joachim Landers[1], Soma Salamon[1], Annette M. Schmidt[2], and Heiko Wende[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen — [2]Institute for Physical Chemistry, University of Cologne

The particle-matrix interaction in complex viscoeleastic composites is determined by the characteristic length scales between the magnetic particles and matrix structures. In this work, we study the particle-matrix interaction of a polyethylene glycol (PEG) polymer solution with tailored complexity and the mobility of two types of particles. Pure cobalt ferrite nanoparticles with a hydrodynamic radius of $r_{h,CFO} = 23.2$nm and cobalt ferrite particles coated with silica resulting in $r_{h,CFO@SiO_2} = 42.3$nm are dispersed in various concentrated polymer solutions with different PEG length. The dynamic properties of the two particle systems in various polymer solutions are characterized by magnetic AC-susceptometry. Here the Brownian relaxation of the particles in complex fluids are investigated in the frequency regime from 0.001 Hz -250 kHz and compared to the relaxation of the coated particles, where a shift of magnetic susceptibility spectra to lower frequencies is observed. The frequency dependent viscosity is also determined by temperature dependent magnetic AC measurements. This work is supported by the DFG-Priority Programme SPP1681.

MA 1.9 Mon 11:45 H 0112

Intermediates and pH sensitive formation pathways of superparamagnetic Fe3O4 nanoparticles — •Mohammad Reza Ghazanfari[1], Seyedeh Fatemeh Shams[1,2], Mehrdad Kashefi[1], and Mahmoud Reza Jaafari[3] — [1]Department of Materials Science and Engineering, Ferdowsi University of Mashhad, 9177948974, Mashhad, Iran — [2]Peter Grünberg Institute (PGI-6), Jülich Research Centre, 52425 Jülich, Germany — [3]Biotechnology Research Center, Nanotechnology Research Center, School of Pharmacy, Mashhad University of Medical Sciences, Mashhad, Iran

In this work, by identification of reaction critical steps using study of pH variations trend and then investigation of structural, microstructural, and magnetic properties of each sample, the formation mechanism and reaction pathways of synthesis the nanoparticles of Fe3O4 (magnetite) phase by coprecipitation method were successfully recognized and presented. Based on the results, the formation mechanism and reaction pathways of magnetite nanoparticles synthesis during coprecipitation method can be explained in four critical steps as follows: (I) the formation of ferrous hydroxide phase from initial materials, (II) the transformation of ferrous hydroxide phase to lepidocrocite phase, (III) the transformation of lepidocrocite phase to goethite phase, and (IV) the transformation of goethite phase to magnetite target phase (or/and maghemite phase).

MA 1.10 Mon 12:00 H 0112

Magnetic properties of shell-ferromagnetic precipitates in decomposed off-stoichiometric Ni-Mn-based Heusler alloys, studied by ferromagnetic resonance (FMR) — •F. Scheibel[1,3], D. Spoddig[1], R. Meckenstock[1], T. Gottschall[2,3], M. Fries[3], A. Çakir[4], M. Farle[1], O. Gutfleisch[3], and M. Acet[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, 47057 Duisburg, Germany — [2]High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [3]Institut für Materialwissenschaft FG Funktionale Materialien, Technische Universität Darmstadt, 64289 Darmstadt, Germany — [4]Department of Metallurgical and Materials Engineering, Muğla Sitki Koçman University, 48000 Mugla, Turkey

Off-stoichiometric $Ni_{50}Mn_{25-y}X_y$ ($25 > y > 0$) Heusler alloys decompose into ferromagnetic (FM) $Ni_{50}Mn_{25}X_{25}$ and antiferromagnetic $Ni_{50}Mn_{50}$ components when annealed between 600 and 750 K [1]. In the case of $y = 5$ annealed at 650 K, shell-ferromagnetic $Ni_{50}Mn_{25}X_{25}$ nano-precipitates of about 3 nm are formed. High-field FMR measurements up to 12 T verify the existence of a strong coupling of the shell of the precipitates with the surrounding $Ni_{50}Mn_{50}$ matrix [2]. Magnetization measurements show a rotation of the shell-spins first above 5 T, while the core shows a soft FM behavior. The magnetic hysteresis is vertically shifted, which makes this material interesting for magnetic-field proof permanent memory application. Work supported by the Deutsche Forschungsgemeinschaft (SPP 1599).

[1] A. Çakir et al., Sci. Rep. 6 , 28931 (2016)
[2] F. Scheibel et al., AIP Adv. 7, 056425 (2017)

MA 2: Focus Session: Nanomagnetism in the x-ray spotlight

X-ray microscopy allows the application of spectroscopic techniques on length scales far smaller than possible with optical microcopy. X-ray absorption contrast allows element and chemically sensitive imaging, while x-ray magnetic circular dichroism (XMCD) allows direct, highly sensitive detection of the sample magnetization. In x-ray microscopy, these contrast mechanisms can be employed at spatial resolutions below 15 nm, and even better using emergent coherent diffractive imaging techniques. Combining this with pump-and-probe imaging with time resolutions of <50 ps makes x-ray microscopy a universal and powerful tool. In this focus session, the fundamentals of x-ray microscopy, current developments of established and novel techniques and their applications to solve open questions in nanomagnetism are discussed.

Organized by: Joachim Gräfe, Markus Weigand, Eberhard Goering (MPI for Intellligent Systems, Stuttgart)

Time: Monday 9:30–12:45 Location: H 1012

Invited Talk MA 2.1 Mon 9:30 H 1012

Advanced X-ray Optics - Zone Plates, Kinoforms and Computer Generated Holograms — •Kahraman Keskinbora, Umut T. Sanli, Margarita Baluktsian, Gül Dogan, Iuliia Bykova, Markus Weigand, and Gisela Schütz — Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany

High penetration depths and short wavelengths of X-rays render X-ray microscopy (XRM) a unique tool in a variety of fields, ranging from materials science to medicine for investigating inorganic and biological matter. The success of XRM was historically built on high-resolution diffractive optics. However, limitations in nanofabrication of high aspect ratio diffractive lenses became a crucial bottleneck. Over the last decade, our group has been developing novel X-ray optics by combining atomic layer deposition and focused ion beam micro-machining techniques to attack this bottleneck from several angles. Resolving 20 to 15 nm features was possible using FZPs fabricated via novel ion-beam-lithography and atomic-layer-deposition methods, respectively. Pushing resolutions of these optics below 20 nm while improving efficiencies is a major goal for us. Here, we will discuss fabrication routes that can help achieve this goal. In addition, we present the nanofabrication processes for point focusing kinoform lenses and kinoforms of higher topological charges, shaping of the intensity profile as well as the phase-front of soft X-rays in order to create beams that carry orbital angular momenta. The challenges and solutions in characterization of these complex X-ray phases will also be discussed.

Invited Talk MA 2.2 Mon 10:00 H 1012

Time-resolved imaging of nanoscale spin textures and spin waves — •Jörg Raabe, Simone Finizio, and Sebastian Wintz — Paul Scherrer Institut, Villigen, Schweiz

The direct imaging of nanoscale spin textures and their dynamics represents a key demand in magnetism research. Scanning transmission x-ray microscopy (STXM) using soft x-rays [e.g. 1] provides unique means for high-resolution, element-selective magnetic imaging, by exploiting diffractive lenses and the x-ray magnetic circular dichroism (XMCD) effect [2]. In particular, time-resolved STXM offers an ultimate combination of spatial and stroboscopic temporal resolution, down to $\Delta r \sim 10$nm, $\Delta t \sim 10$ps. In this contribution, we will present three examples of state of the art dynamic STXM imaging. In the first example, magnetoelastic coupling is used to control the intrinsic anisotropy of a vortex spin texture. This control results in drastic changes of the vortex core gyration frequency and orbit which were directly imaged in the experiment [3]. In the second part, we will show dynamic imaging of a remnant topological bubble at room temperature in a low-pinning iron-nickel alloy with weak perpendicular magnetic anisotropy. Finally, we will present how such topological spin textures can be exploited as natural antennas for the coherent excitation of nanoscale spin waves, which have also been directly observed [4].

[1] J. Raabe et al. Rev. Sci. Instrum. 79, 113704 (2008).
[2] G. Schütz et al. Phys Rev. Lett. 58, 737 (1987).
[3] S. Finizio et al. Phys. Rev. B 96, 054438 (2017).
[4] S. Wintz et al. Nat. Nanotechnol. 11, 948 (2016).

Invited Talk MA 2.3 Mon 10:30 H 1012

Direct observation of magnetic droplet solitons — •Martina Ahlberg[1], Sunjae Chung[1,2,3], Q. Tuan Le[1,2], Ahmad A. Awad[1], Markus Weigand[4], Iuliia Bykova[4], Roman Khymyn[1], Mykola Dvornik[1], Hamid Mazraati[2], Afshin Houshang[1], Sheng Jiang[2], T. N. Anh Nguyen[1,2,5], Eberhard Goering[4], Gisela Schütz[4], Joachim Gräfe[4], and Johan Åkerman[1,2] — [1]University of Gothenburg, Gothenburg, Sweden — [2]KTH Royal Institute of Technology, Kista, Sweden — [3]University Uppsala, Uppsala, Sweden — [4]Max Planck Institute for Intelligent Systems, Stuttgart, Germany — [5]Vietnam Academy of Science and Technology, Hanoi, Vietnam

The magnetic droplet is a localized excitation found in uniaxial ferromagnets where a polarized current provides sufficient spin transfer torque to counteract the inherent damping. This dissipative soliton was first detected in nanocontact spin torque oscillators (NC-STO). The droplet is created underneath the contact and is predicted to have a reversed core where the spins precess at angles almost antiparallel to the initial state. However, the first images of a droplet revealed much smaller precession angles.

In this work we use all-perpendicular NC-STOs and image the spin wave excitation by X-ray microscopy. We observe a fully reversed droplet core, in accordance with theory, while the droplet diameter is twice as big as the expected value. Micromagnetic simulations show that the origin of the enlargement is current-in-plane Zhang-Li torque adding an outward pressure on the droplet perimeter. We also image the evolution of the magnetic state as a function of current and field.

15 minutes break

Invited Talk MA 2.4 Mon 11:15 H 1012

Studying nanomagnets by XMCD PEEM — •Florian Kronast — Helmholtz-Zentrum Berlin für Materialien und Energie

At the nanoscale magnetic materials exhibit novel physical, chemical, electrical, and optical properties that are relevant to a wide variety of applications. Investigations of static and dynamic properties of such low-dimensional structures require spectro-microscopy tools capable of appropriate lateral and temporal resolution, such as the synchrotron based photoemission electron microscope (PEEM) operated at Hemholtz-Zentrum Berlin. The combination of element-specific magnetic contrast with temporal and lateral resolution offers a unique toolbox for magnetic nanoscale science. This paper will present a review on recent activities ranging from the investigation of magnetic nanostructures found in meteorites to the microscopic mechanism behind all-optical magnetic switching and its scalability to the nanometer level.

Invited Talk MA 2.5 Mon 11:45 H 1012

A time-resolved view on magnetic domains and spin textures by x-ray holography — •Stefan Eisebitt — Max Born Institute, Berlin, Germany

Fourier transform X-ray holography is a high resolution imaging technique when performed with soft x-rays.[1] As it is based on interference of an object beam with a reference beam, it requires coherent illumination and is thus particularly well suited for use at 3rd generation and diffraction limited storage rings and free electron lasers. When combined with magnetic contrast via x-ray magnetic circular dichroism, it has been very successfully used for the study of magnetism on the nanometer length scale. I will briefly review the specific capabilities of this imaging approach, where a single hologram can be used to encode images of several samples simultaneously, of a sample seen at different x-ray wavelengths, of a sample seen at different times or including 3D information.[2] Results of the first time resolved experiments at synchrotron sources and free electron lasers down to femtosecond temporal resolution will be presented, including work on skyrmions and magnetic data storage [3,4,5] and ultrafast light-induced manipulation of magnetization.[6] [1] S. Eisebitt et al., Nature 432, 885 (2004). [2] B. Pfau and S. Eisebitt, X-ray holography, in: ISBN 978-3-319-14395-8 (2016). [3] B. Pfau et al.:, Appl. Phys. Lett. 99 062502 (2011) & Appl. Phys. Lett. 105 132407 (2014) [4] F. Büttner et al., Nature Physics 11, 225 (2015). [5] F. Büttner et al., Nature Nanotechnology 12, 1040 (2017) [6] von Korff Schmising et al., Phys. Rev. Lett. 112 217203 (2014).

MA 2.6 Mon 12:15 H 1012

Room temperature ferromagnetism in EuO revealed by XMCD — •Patrick Lömker[1], Marek Wilhelm[1], Ronja Heinen[1], Mai Hussein[1], Andrei Gloskovskii[2], Wolfgang Drube[2], Peter Bencok[3], Paul Steadman[3], and Martina Müller[1,4] — [1]PGI-6, FZ Jülich GmbH, Jülich, DE — [2]Photon Science, DESY, Hamburg, DE — [3]DIAMOND Light Source, Oxford, GB — [4]Fakultät Physik, TU Dortmund, Dortmund, DE

The Heisenberg model system EuO is both a 4f ferromagnet and an electric insulator. This rare combination exhibits both fundamentally and technologically exciting properties, however limited to $T < 70$ K. We study interface effects between EuO and the 5d metal Pt and the itinerant 3d ferromagnet Co, enhancing T_C up to room-temperature.

While electron doping is typically utilized to enhance the T_C of EuO, we employ a hole-doped EuO/Pt interface instead. Pt virtual substrates are prepared on $SrTiO_3$(001), the Pt surface state is observed by LEED. EuO is deposited using the adsorption-limited growth mode. We observe an enhanced T_C with HAX-MCD and check our results with VSM. Our findings agree with a recent DFT study of a Pt/EuO/Pt system, which predicts a 2D hole gas at the EuO/Pt interface and a strong hybridization of the Eu 4f and O 2p bands.

Furthermore, we study the Co/EuO interface with XMCD. The EuO films are grown by a novel redox method on $SrTiO_3$(001). EuO ferromagnetism at room temperature is observed and we determine the coupling strength and -length revealing a strong magnetic proximity effect between the 3d/4f ferromagnets.

MA 2.7 Mon 12:30 H 1012

Element-specific characterization of Co:FePt nanocomposite magnet films — •Fabrice Wilhelm[1], Veronique Dupuis[2], Damien Le Roy[2], Nora Dempsey[3], and Andrei Rogalev[1] — [1]European Synchrotron Radiation Facility, Grenoble, France — [2]Institut Lumière Matière, Villeurbanne, France — [3]Institut Néel, Grenoble, France

Nanocomposite magnets consisting of a fine mixture of a hard magnetic phase and a high saturation magnetization phase are promising systems to overpass performances of the best permanent magnets. To achieve this aim, it is necessary to confine the soft magnetic phase in grains of typically less than 10nm [1]. Here we report on thorough study of Co:FePt nanocomposite where Co nanoclusters with size of 6 nm constitute the soft magnetic phase which is embedded in L10-FePt matrix. Standard structural (e.g. XRD, SEM, TEM) and magnetic (SQUID magnetometry, MFM) characterizations were complemented with X-ray natural linear dichroism (XLD) and X-ray magnetic circular dichoism (XMCD) spectroscopies at the K-edges of Fe and Co. XLD measurements confirmed that Co is embedded in FePt matrix. XMCD measurements in turn show that Co and Fe atoms are ferromagnetically coupled and that the Co:FePt nanocomposite behaves like a single magnetic phase.

Funding by the ANR-SHAMAN (ANR-16-CE09-0019) is acknowledged.

[1]Skomski R. and Coey J. M. D. Giant energy product in nanostructured two-phase magnets. Phys. Rev. B 48, 15812 (1993).

MA 3: Quantum Magnets and Molecular Magnets (joint session TT/MA)

Time: Monday 9:30–13:00 Location: H 3010

MA 3.1 Mon 9:30 H 3010

Frustrated spin ladders in quasi-1D $S=\frac{1}{2}$ Heisenberg magnet balyakinite $CuTeO_3$ — •Helge Rosner[1] and Oleg Janson[2] — [1]Max-Planck-Institut für Chemische Physik fester Stoffe, Dresden, Deutschland — [2]Institut für Festkörperphysik, TU Wien, Österreich

Copper tellurium oxides are enjoying increasing attention as a promising playground for quantum magnetism [1]. A chemically simple compound, the natural mineral balyakinite $CuTeO_3$ features an intricate crystal structure with Cu_2O_6 dimers connected by TeO_4 tetrahedra into a 3D network. Magnetization measurements indicate a sizable spin gap which is not closed in a magnetic field of 60 T. By using DFT calculations, we show that the magnetism of balyakinite is quasi-1D, and can be described by a frustrated ladder model with four antiferromagnetic exchanges: the dominant rung exchange $J_\perp$, sizable $J_\parallel$ and weak $J'_\parallel$ that alternate along both legs, as well as the weak frustrated cross-coupling $J_\times$. Using the DFT+U estimates of the exchange integrals, we calculate the spin correlations in the ground state. Peculiarities of the magnetic excitation spectrum will be briefly discussed. [1] M. R. Norman, arXiv:1708.05100.

MA 3.2 Mon 9:45 H 3010

Extreme field-sensitivity of the magnetic tunnelling in Fe-doped Li_3N — •Manuel Fix[1], James H. Atkinson[2], Paul C. Canfield[3,4], Enrique del Barco[2], and Anton Jesche[1] — [1]EP VI, EKM, University of Augsburg, D-86159, Germany — [2]Department of Physics, UCF, Orlando FL 32816, USA — [3]The Ames Laboratory, ISU, Ames, Iowa 50011, USA — [4]Department of Physics and Astronomy, ISU, Ames, Iowa 50011, USA

The magnetic properties of dilute $Li_2(Li_{1-x}Fe_x)N$ with $x \sim 0.001$ are dominated by the spin of single, isolated Fe atoms [1]. Below $T = 10$ K the spin-relaxation times become temperature-independent, indicating a crossover from thermal excitations to the quantum tunnelling regime.

The spin-flip probability increases tremendously in *transverse* magnetic fields, proving the resonant character of this tunnelling process. Upon application of *longitudinal* fields, on the other hand, the ground-state degeneracy is lifted and the tunnelling condition destroyed. We show time dependent magnetization measurements performed on single crystals in various longitudinal magnetic fields at temperatures $T = 2-16$ K. An increase of the relaxation time by four orders of magnitude in applied fields of only a few milliTesla reveals exceptionally sharp tunnelling resonances. This strong field dependence of the spin reversal could be employed to create stable ($\mu_0 H_z = 3$ mT) but switchable ($H_z = 0$) magnetic 'quantum bits' at elevated temperatures.
[1] A. Jesche *et al.*, Nature Comm. **5**:3333 (2014)

MA 3.3 Mon 10:00 H 3010

In- & interchain exchange constants of Li_2CuO_2: the origin of the ferromagnetic inchain ordering — •S.-L. Drechsler[1], R. Klingeler[2], W. Lorenz[2], R. Kuzian[3], L. Hozoi[1], R. Jadav[1], J. Richter[4], H. Rosner[5], U. Nitzsche[1], A. Tsirlin[6], and S. Nishimoto[1,7] — [1]IFW-Dresden, Germany — [2]Heidelberg University, Germany — [3]Inst. f. Problems of Material Science, Kiev, Ukraine — [4]MPI-PKS, Dresden, Germany — [5]MPI-CPfS, Dresden, Germany — [6]Augsburg University, Germany — [7]TU Dresden, Germany

Li_2CuO_2 takes a special place among frustrated chain compounds with edge-sharing CuO_4 units and a ferromagnetic (FM) nearest neighbor (NN) in-chain coupling J_1 due to its ideal planar CuO_2 chain structure and its well-defined 3D Neél-type ordering below $T_N \approx 9$ K of adjacent chains whose magnetic moments are aligned FM along the chains (*b*-axis). There are only frustrating AFM *interchain* couplings (IC) with adjacent chains *shifted* by half a lattice constant *b*. *No* room is left for strong unfrustrated IC in shtark contrast with a recently proposed scenario [1]. The AFM IC with dominant NNN components plays a decisive role in the stabilization of the FM alignment of the magnetic moments along b. Although weak, with 8 NNN IC it is significant enough to prevent a competing non-collinear spiral type ordering. We report realistic values of all relevant exchange constants based on two DFT and quantum chemistry calculations in full accord with a spin-wave analysis of INS, RIXS, and magnetic susceptibility $\chi(T)$ data. The large $J_1 \approx$ -230 K is ascribed to a sizable direct FM Cu-O coupling $K_{pd} \approx 100$ meV.
[1] G. Shu *et al.*, New J. Phys. **19**, 023026 (2017).

MA 3.4 Mon 10:15 H 3010

Magnetic susceptibility and high frequency EPR studies on three isostructural $Fe_2^{III}Ln_2^{III}$ complexes — •Silvia Menghi[1], Changhyun Koo[1], Yan Peng[2], Christopher Anson[2], Annie Powell[2], and Rüdiger Klingeler[1] — [1]Kirchhoff-Institut für Physik, Universität Heidelberg, Heidelberg, Germany — [2]Institute of Inorganic Chemistry, Karlsruhe Institut of Technology, Karlsruhe, Germany

Magnetic interactions and anisotropy of three 3d/4f heteronuclear metal-organic complexes are studied by means of high-frequency electron paramagnetic resonance (HF-EPR) and magnetic susceptibility measurements. All complexes under study exhibit isostructural tetranuclear core motifs $[(Fe_2^{III}Ln_2^{III}(\mu_3\text{-}OH)_2(teaH)_2(O_2CCPh)_6]\cdot 3MeCN$ (L=Y,Gd,Dy). The HF-EPR data show various resonance branches, each of which with finite zero field splitting. The static magnetic susceptibility data imply strong antiferromagnetic coupling of $J_{\rm FeFe} = -6.71(4)$ cm^{-1} between the two Fe^{III} centers. The coupling between Fe and Ln was found to be weak and ferromagnetic. In order to gain quantitative insight into the anisotropy and the Fe-Dy exchange interaction, simulations have been performed using a proper hamiltonian which applies a Ising concept for the lanthanide ions.

MA 3.5 Mon 10:30 H 3010

Effect of radicals on coupling and anisotropy in mono- and dinuclear Ni(II) complexes with an azopyridine ligand — •Sven Spachmann[1], Roland Bischoff[2], Changhyun Koo[1], Hans-Jörg Krüger[2], and Rüdiger Klingeler[1,3] — [1]Kirchhoff Institute for Physics, Heidelberg University, Heidelberg, Germany — [2]Faculty of Chemistry, TU Kaiserslautern, Kaiserslautern, Germany — [3]Center for Advanced Materials, Heidelberg University, Heidelberg, Germany

We present static magnetization and high-frequency electron paramagnetic resonance (HF-EPR) studies on metallorganic mono- and dinuclear Ni(II)-complexes with radical and non-radical azopyridine ligands. In the monomer, the radical is coupled ferromagnetically to the Ni(II) spin, thereby forming an $S = 3/2$ ground state. In the non-radical mononuclear system, anisotropy is of the easy-plane type with $D_{\rm Ni} = 4.0$ K and $|E| = 0.32$ K.

We observe a strong effect of the radical bridge on the dimer systems: While the non-radical azopyridine-bridged Ni(II)-dimer has a singlet ground state with a weak intradimer coupling of $J \approx 20$ K, a strong ferromagnetic coupling $J_{\rm Ni-rad} \approx -500$ K is observed in the radical azopyridine-bridged Ni(II)-dimer between the radical and the Ni(II)-ions. The antiferromagnetic Ni-Ni coupling in the radical-bridged dimer $J_{\rm Ni-Ni} = 25$ K is of the same order as without the radical. The HF-EPR and magnetization measurements confirm the $S = 5/2$ ground state and axial symmetry. We obtain $g_z = 2.126$ and $D_{5/2} = -0.844$ K, which corresponds to a single-ion anisotropy of $|D_{\rm Ni}| = 4.2$ K.

MA 3.6 Mon 10:45 H 3010

Highly dispersive magnons with spin-gap like features in the frustrated ferromagnetic chain system $Ca_2Y_2Cu_5O_{10}$ by inelastic neutron scattering — M. Matsuda[1], J. Ma[1], V.O. Garlea[1], T. Ito[2], H. Yamaguchi[2], K. Oka[2], •S.-L. Drechsler[3], R. Yadav[3], L. Hozoi[3], H. Rosner[4], R. Schumann[5], R. Kuzian[6], and S Nishimoto[3,5] — [1]Quantum Matter Division, Oak Ridge, NRL, USA — [2]Natiomal Institute of AIST, Tsukuba, Japan — [3]IFW-Dresden, Germany — [4]MPI-CPfS, Dresden, Germany — [5]TU Dresden, Germany — [6]Inst. f. Problems of Material Science, Kiev, Ukraine

We report an inelastic neutron scattering study including its theoretical description for $Ca_2Y_2Cu_5O_{10}$ and map out the full large magnetic dispersion relation extending up to 53 meV. A doubly frustrated linear Heisenberg-type spin chain model with two inchain and two diagonal antiferromagnetic (AFM) interchain couplings (IC) analyzed within linear spin-wave theory reproduces well the observed strong dispersion in chain direction and q weak one perpendicularly. The large dispersion leads to a record value of the NN intrachain coupling $| J_1 |\approx 280$ K which points to a large direct FM Cu-O coupling K_{pd} value slightly above 100 meV. Our J_1-value resolves an old puzzle of FM inchain ordering vs. an improper AFM pseudo Curie-Weiss (CW) behavior for $\chi(T)$. It yields a true FM CW-regime above 1500 K, only. The observed "gaps" at 11.5 and 28 meV stem from an interaction with a phonon mode and the synenergetic disorder influence on the CuO_2 chains by the incommensurate alternating cationic YCa-chains distorting the O positions and a specific quantum effect from the AFM IC, respectively.

MA 3.7 Mon 11:00 H 3010

Magnetism of atacamite, $Cu_2Cl(OH)_3$ — •Leonie Heinze[1], Randirley Beltran-Rodriguez[2], Gael Bastien[2], Anja U.B. Wolter[2], Manfred Reehuis[3], Jens-Uwe Hoffmann[3], Kirrily C. Rule[4], and Stefan Süllow[1] — [1]IPKM, TU Braunschweig, Germany — [2]IFW Dresden, Dresden, Germany — [3]HZB, Berlin, Germany — [4]ANSTO, Kirrawee, Australia

Atacamite, $Cu_2Cl(OH)_3$, has been reported to exhibit magnetic behavior characteristic of a frustrated quantum magnet. Notably, an antiferromagnetic transition at $T_N = 9.0$ K has been observed and, further, susceptibility measurements previously carried out indicate a Curie-Weiss temperature $|\Theta_{CW}| \gg T_N$ [1,2]. So far, attempts have been undertaken to determine the symmetry of the magnetic ground state of this material by means of μSR and NMR measurements on polycrystalline material [2,3], however with contradictory results.

Starting from this given situation, we have reinvestigated the magnetic properties of atacamite [4]: Mineral single-crystals were studied by means of susceptibility and magnetization measurements along the principal crystal axes as well as elastic neutron scattering. This way, we have established the symmetry of the magnetic ground state and present new insights into the unusual magnetic properties of atacamite.

[1] X. G. Zheng, *et al.*, Solid State Commun. **130**, 107 (2004).
[2] X. G. Zheng, *et al.*, Phys. Rev. B, **71**, 174404 (2005).
[3] K. Zenmyo, *et al.*, J. Phys. Soc. Jpn., **82**, 084707 (2013).
[4] L. Heinze, *et al.*, Physica B, doi.org/10.1016/j.physb.2017.09.073 (2017).

15 min. break.

MA 3.8 Mon 11:30 H 3010

Alternating ferro- and antiferromagnetic Heisenberg chain: from dimer to Haldane limit — •Niklas Casper and Wolfram Brenig — Institute for Theoretical Physics, Technical University Braunschweig, Braunschweig, Germany

We present results of a study of the $S = 1/2$ Heisenberg chain with alternating ferro- and antiferromagnetic exchange, J_2 and J_1 respectively. This system interpolates from a dimer to a Haldane chain as $j = |J_2/J_1|$ varies from 0 to ∞. Using perturbation theory (PT) and quantum Monte Carlo based on the stochastic series expansion (SSE) method, we study elementary excitations, thermodynamic properties, and the dynamic structure factor $S(\mathbf{q}, \omega)$. For $j \ll 1$ we find good agreement between PT and SSE. For arbitrary j we show that $S(\mathbf{q}, \omega)$, obtained from SSE, scales between triplons at $j \ll 1$ and a Haldane chain spectrum at $j \gg 1$. Finally, we contrast our findings for the spin gap versus j against existing literature.

MA 3.9 Mon 11:45 H 3010

Field Control of Magnonic Heat Flow — •Benjamin Köhler and Wolfram Brenig — Institute for Theoretical Physics, Technical University Braunschweig, Germany

Insulating quantum magnets allow for genuine spin transport phenomena without carrier dynamics. Controlling such transport by means of external fields is vital for potential device design. Here we study thermal conductivity of a two dimensional square lattice spin-1/2 Heisenberg antiferromagnet in the presence of an external field. The latter is used to manipulated the heat flow due to spin canting.

Using nonlinear spin wave theory and a Kubo approach we evaluate the thermal conductivity taking into account current relaxation via intrinsic magnon decay for finite fields and temperature. Semi-quantitative estimates for attainable variations of the heat conductivity in realistic materials will be presented as a function of the temperature and the external fields, suggesting interesting implications for spin caloritronic applications.

MA 3.10 Mon 12:00 H 3010

Suppression of spin-crossover by dynamic Jahn-Teller effect in C_{60}^{3-} — •Dan Liu, Naoya Iwahara, and Liviu Chibotaru — Theory of Nanomaterials Group, University of Leuven, Leuven, Belgium

In conventional spin crossover systems, the vibrational degrees of freedom enhances the entropic effect in excited high-spin terms resulting from the softening of vibrations [1]. Here, we show an opposite effect of vibration on the spin crossover taking C_{60}^{3-} as an example [2]. The vibronic states resulting from dynamical Jahn-Teller effect in C_{60}^{3-}

are obtained using the numerical diagonalization of the linear $p^n \otimes 8d$ Jahn-Teller Hamiltonian with the currently established coupling parameters. It is found that the Jahn-Teller effect stabilizes the low-spin states, resulting in the violation of Hund's rule. The energy gain due to the Jahn-Teller dynamics is found to be comparable to the static Jahn-Teller stabilization. The Jahn-Teller dynamics influences the thermodynamic properties via strong variation of the density of vibronic states with energy. Thus, the large vibronic entropy in the low-spin states enhances the effective spin gap of C_{60}^{3-} quenching the spin crossover. This finding is used for the rationalization of the experimental data on the spin gaps in various fullerides.

[1] P. Gütlich, A. Hauser, and H. Spiering, Angew. Chem. Int. Ed. 33, 2024 (1994).
[2] D. Liu, N. Iwahara, and L. F. Chibotaru, arXiv:1711.00340 [cond-mat.mtrl-sci].

MA 3.11 Mon 12:15 H 3010

Andreev transport through single-molecule magnets — •Filip Pawlicki and Ireneusz Weymann — Faculty of Physics, Adam Mickiewicz University, ul. Umultowska 85, 61-614 Poznań, Poland

Transport characteristics of a single molecule magnet coupled to two ferromagnetic and one superconducting lead are studied theoretically by means of the real-time diagrammatic technique. The coupling to the ferromagnets is assumed to be weak, while the coupling to the superconductor can be arbitrary. The quantities of interest include the Andreev current, differential conductance, tunnel magnetoresistance (TMR) and current cross-correlations. It is shown that the system exhibits splitting of Andreev states due to additional degrees of freedom of the molecule. The TMR and current cross-correlations are used to quantify the contribution of crossed and direct Andreev reflections to the current. We also compare our results to those obtained for a quantum dot in a similar three-terminal setup and discuss the possibility of using molecules for Cooper pair splitting.

MA 3.12 Mon 12:30 H 3010

Manifestations of a coherent Kondo lattice formed in adatoms — •Richard Korytár[1], María Moro Lagares[2], and David Serrate[3] — [1]Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic — [2]Institute of Physics, Czech Academy of Sciences, Prague, Czech Republic — [3]Institute of Nanoscience of Aragon (INA), University of Zaragoza, Spain

In a recent experiment, chains of magnetic adatoms were constructed on a pristine metallic surface. A careful analysis by scanning-tunneling spectroscopy demonstrates that the Kondo screening overtakes magnetic interactions at all accessible chain lengths. A comparison with many-body calculations allows to address diverse real space aspects of the coherent Kondo lattice, such as: overlapping Kondo clouds, long-range mediated hybridization and Fermi surface effects. The phenomenology of the onset of heavy fermions in these systems can be discussed.

MA 3.13 Mon 12:45 H 3010

Formation of Local Magnetic Order in Atomic-Scale Ir Junctions — •Markus Ritter, Martin Keller, Torsten Pietsch, and Elke Scheer — Department of Physics, University of Konstanz, D-78467 Konstanz, Germany

The transition metals Pt, Pd, and Ir are paramagnets close to the Stoner transition of ferromagnetism. However, in reduced dimensions, such as small clusters and atomic contacts, a magnetically ordered state has been predicted [1]. In atomic contacts of the elements Pt and Pd, the emergence of local magnetic order has been experimentally confirmed recently [2, 3]. Currently there is no demonstration of such phenomena in Ir. Therefore, we investigate the magnetic properties of atomic Ir contacts and monoatomic chains [4]. The occurrence of local magnetic order is deduced from magnetoconductance (MC) and anisotropic magnetoconductance (AMC) measurements. The rich MC behavior is interpreted in the framework of a microscopic model of the local magnetic configuration and is compared to earlier findings in Pt and Pd contacts. Furthermore, in many contacts electronic transport (dI/dV) spectroscopy shows a pronounced zero-bias anomaly (ZBA) and further features, which are currently not fully understood. The ZBA is analyzed in the context of Kondo screening of the local magnetic moment in the junction.

[1] Delin, Tosatti. Phys. Rev. B **68**, 144434 (2003).
[2] Strigl et al. Nat. Commun. **6**, 6172 (2015).
[3] Strigl et al. Phys. Rev. B **94**, 144431 (2016).
[4] Thiess et al. Phys. Rev. Lett. **103**, 217201 (2009).

MA 4: Spin structures and magnetic phase transitions

Time: Monday 9:30–12:45 Location: EB 202

MA 4.1 Mon 9:30 EB 202

Nature of spiral state, electric polarisation and magnetic transitions in Sr-doped $YBaCuFeO_5$ from first-principles study — Dibyendu Dey[1], Snehasis Nandy[1], •Tulika Maitra[2], Chandra Shekhar Yadav[3], and Arghya Taraphder[1] — [1]Department of Physics, Indian Institute of Technology Kharagpur, Kharagpur 721302, India — [2]Department of Physics, Indian Institute of Technology Roorkee, Roorkee -247667, India — [3]School of Basic Sciences, Indian Institute of Technology Mandi, Mandi 175001, India

The nature of the spiral magnetic state in type II multiferroic $YBaCuFeO_5$ has recently been a matter of debate. Using first-principles density functional theory (DFT) calculations within LSDA+U+SO approximation, we reveal the nature of spiral state and corresponding ferroelectric response in the incommensurate magnetic phase of $YBaCuFeO_5$. A helical spiral state with spins living in the ab-plane is found to be more stable. Owing to negligibly small Dzyaloshinskii-Moriya interaction and the absence of any spin current mechanism in the helical spiral state, electric polarization is predicted to be zero. These results are in good agreement with the recent single-crystal data. We further investigated $YBa_{1-x}Sr_xCuFeO_5$) in the entire range of doping x. A quantum Monte Carlo (QMC) calculation on an effective spin Hamiltonian with exchange interactions estimated from DFT calculations shows that the paramagnetic to commensurate phase transition temperature increases with doping till x=0.5 and decreases beyond consistent with experimental findings.

MA 4.2 Mon 9:45 EB 202

Magnetism in High-Pressure Iron — •Tommaso Gorni and Michele Casula — IMPMC, Univeristé Pierre et Marie Curie, Paris

Due to the high pressures involved, the vast majority of iron contained in the Earth's interior, from the upper mantle to the lower core, is found in the so-called ε-Fe phase, displaying an hcp structure and a lack of macroscopic magnetization. However, in the pressure range of 15-30 GPa, ε-Fe presents several fingerprints of an underlying magnetic state, among which superconductivity, believed to be mediated by antiferromagnetic fluctuations. First-principles simulations of paramagnetic and antiferromagnetic states both reproduce the experimental equation of state with a similar level of accuracy, whereas experimental evidence could not detect any magnetic splitting via Mössbauer spectroscopy on the one side, but suggested antiferromagnetic order via an anomalous Raman splitting on the other. Here, we perform a thorough re-investigation of the ε-Fe antiferromagnetic states by Density Functional Theory calculations, and we map our results onto a spin model that we solve via a classical Monte Carlo approach. We finally propose a new scenario where the long-range magnetic ordering is hampered by spins fluctuating in both amplitude and direction, as suggested by our first-principles calculations. Our results are supported by some very recent X-ray Emission Spectroscopy and Neutron Scattering data.

MA 4.3 Mon 10:00 EB 202

Comparison of diluted antiferromagnetic Ising models on frustrated lattices in a magnetic field — •Konstantin Soldatov[1], Alexey Peretyatko[1], Konstantin Nefedev[1], and Yutaka Okabe[2] — [1]Far Eastern Federal University, Vladivostok, Russia — [2]Tokyo Metropolitan University, Tokyo, Japan

We study diluted antiferromagnetic Ising models on kagome and triangular lattices in a magnetic field, using the replica-exchange Monte Carlo method. We observe five and seven plateaus in the magnetization curve of the diluted antiferromagnetic Ising model on the kagome and triangular lattices, respectively, when a magnetic field is applied. These observations contrast with the two plateaus observed in the pure model. The origin of multiple plateaus is investigated by considering the spin configuration of triangles in the diluted models. We compare these results with those of a diluted antiferromagnetic Ising model on the three-dimensional pyrochlore lattice in a magnetic field pointing in the [111] direction, sometimes referred to as the "kagome-ice" problem. We discuss the similarity and dissimilarity of the magnetization curves of the "kagome-ice" state and the two-dimensional kagome lattice.

MA 4.4 Mon 10:15 EB 202

Entropy of the diluted antiferromagnetic Ising models on the frustrated lattices using the Wang-Landau method — •Yuriy Shevchenko[1,2], Konstantin Nefedev[1,2], and Yutaka Okabe[3] — [1]School of Natural Sciences, Far Eastern Federal University, Vladivostok, Russian Federation — [2]Institute of Applied Mathematics, Far Eastern Branch, Russian Academy of Science, Vladivostok, Russian Federation — [3]Department of Physics, Tokyo Metropolitan University, Hachioji, Tokyo 192-0397, Japan

We show the results of computer calculations of non-linear behavior of residual entropy on frustrated pyrochlore, triangular and kagome lattices.

Nonmonotonic zero-point entropy as a function of dilution concentration was observed experimentally and discussed in frames of generalization of Pauling's theory [Ke X. et al., Phys. Rev. Lett. 99, 137203 (2007)]. Motivated by the current interest in the pyrochlore lattice, we study the entropy of the diluted AFM Ising model on the frustrated lattices using the Wang-Landau algorithm, which directly calculates the energy density of states.

We also investigate other frustrated systems, the antiferromagnetic Ising model on the triangular lattice and the kagome lattice, demonstrating the difference in the dilution effects between the system on the pyrochlore lattice and that on other frustrated lattices, and discuss it's nonmonotonic behavior.

MA 4.5 Mon 10:30 EB 202

Optical study of vibronic coupling in the quantum spin liquid candidate Tb2Ti2O7 — •Evan Constable[1,2], R. Ballou[1], J. Robert[1], L Bergen[2], C. Decorse[3], J.-B. Brubach[4], P. Roy[4], E. Lhotel[1], V. Simonet[1], S. Petit[5], and S. deBrion[2] — [1]Institut Néel, CNRS and Université Grenoble Alpes, Grenoble, France — [2]Institute of Solid State Physics, Vienna University of Technology, Vienna, Austria — [3]ICMMO, Université Paris-Sud, Orsay, France — [4]Synchrotron SOLEIL, Gif-sur-Yvette, France — [5]Laboratoire Léon Brillouin, CEA, CNRS, Université Paris-Saclay, Gif-sur-Yvette, France

Vibronic coupling describes the interaction between electronic energy levels and phonon modes, often leading to a ground state that is considerably perturbed. In magnetic rare-earth pyrochlores (RE2Ti2O7, RE = Dy, Ho), large crystal field splitting of the electronic energy levels leads to exotic magnetic behaviour in the form of a highly degenerate spin ice ground state. The possibility that quantum fluctuations due to vibronic coupling could melt the spin ice state forming a quantum spin liquid, is an interesting prospect. It is thought that this process could be present in Tb2Ti2O7 as it does not appear to feature long range order nor a spin ice phase. Indeed, our investigations reveal favourable symmetry and energy conditions for vibronic coupling. Using optical spectroscopic techniques we find evidence of a hybridisation of crystal-field-phonon modes present across a broad temperature range. This vibronic process supports a collective state between the ground and excited levels, which provides a crucial path for quantum spin-flip fluctuations that inhibit the stabilisation of conventional magnetism.

MA 4.6 Mon 10:45 EB 202

Metamagnetic anomalies near dynamic phase transitions — •Patricia Riego[1,2], Paolo Vavassori[1,3], and Andreas Berger[1] — [1]CIC nanoGUNE, San Sebastian, Spain — [2]University of the Basque Country, Bilbao, Spain — [3]Ikerbasque, Bilbao, Spain

Ferromagnets that are subjected to an oscillating magnetic field H(t) can undergo a second order dynamic phase transition (DPT) at a critical period Pc, when the period P of H(t) becomes comparable to the intrinsic relaxation time of the system, which then gives rise to a non-vanishing period-averaged magnetization for P<Pc [1]. Decades of research have shown that the DPT belongs to the same universality class as the corresponding thermodynamic phase transition (TPT) that spin systems undergo as a function of temperature, and that both phase transitions exhibit equivalent properties close to the critical point [2,3]. In our detailed experimental and theoretical study, however, we find that the equivalency between DPTs and TPTs breaks down in the regime of slow critical dynamics [4]. Instead, we observe a dynamically disordered phase that exhibits metamagnetic anomalies that are absent in TPTs for equivalent spin systems. Furthermore, we show that the scaling regime of the DPT is significantly reduced, which has severely impacted all existing experiments on the DPT to date.

[1] T. Tomé and M. J. de Oliveira, Phys. Rev. A 41, 4251 (1990). [2] G. Korniss, C. J. White, P. A. Rikvold, and M. A. Novotny, Phys. Rev. E 63, 016120 (2000). [3] A. Berger, O. Idigoras, and P. Vavassori, Phys. Rev. Lett. 111, 190602 (2013). [4] P. Riego, P. Vavassori, and A. Berger, Phys. Rev. Lett. 118, 117202 (2017).

MA 4.7 Mon 11:00 EB 202

Magnetism and H-T phase diagram of the C14 Laves phase Nb0.075Fe2.025 compound — •Stanislaw Dubiel[1] and Maria Balanda[2] — [1]AGH University of Science and Technology, Krakow, Poland — [2]Institute of Nuclear Physics, PAN, Krakow, Poland

A C14 Nb0.975Fe2.025 Laves phase compound was investigated aimed at determining the H-T magnetic phase diagram. Magnetization, M, and AC magnetic susceptibility measurements were performed. Concerning the former field-cooled and zero-field-cooled M-curves were recorded in the temperature range of 2-200K and in applied magnetic field, H, up to 1000 Oe, isothermal M(H) curves at 2 K, 5 K, 50 K, 80 K and 110 K as well as hysteresis loops at several temperatures over the field range from -10 to +10kOe. Regarding the AC susceptibility, both real and imaginary components were registered as a function of increasing temperature in the interval of 2 K - 150 K at the frequencies of the oscillating field from 3 Hz up to 999 Hz. An influence of an external DC magnetic field, H, on the temperature dependence of the AC suscpetibility was investigated, too. The measurements clearly demonstrated that the magnetism of the studied sample is weak, itinerant and has a reentrant character which is a novel observation. Based on the obtained results a magnetic phase diagram has been constructed in the H-T coordinates. The results have been validated in terms of the known models for the reentrant spin glasses.

15 minutes break

MA 4.8 Mon 11:30 EB 202

Magnetic characterization of the nanolaminated magnetic Mn_2GaC MAX phase — •Iuliia Novoselova[1], Ruslan Salikhov[1], Arni Ingason[2], Marina Spasova[1], Johanna Rosen[2], Ulf Wiedwald[1,3], and Michael Farle[1,4] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Duisburg, Germany — [2]Department of Physics, Linköping University, Linköping, Sweden — [3]National University of Science and Technology MISIS, Moscow, Russia — [4]Center for Functionalized Magnetic Materials, Immanuel Kant Baltic Federal University, Kaliningrad, Russia

Inherently nanolaminated $M_{n+1}AX_n$ (n=1,2,3) compounds - MAX phases - attract interest, since these materials provide unique anisotropic structural and physical properties [1]. Additionally, materials share properties associated with ceramics and metals [1]. The ternary Mn_2GaC MAX phase has been synthesized as a heteroepitaxial film with Mn as the exclusive M element [2]. We performed a comprehensive study of the temperature-dependent magnetization, magnetoresistive (MR) and magnetostrictive (MS) properties. The system exhibits complex antiferromagnetic states with spin-reorientation transition at T_t = 214 K. Large uniaxial MS of 450 ppm with sign inversion at T_t was observed. MS is accompanied by highly asymmetric MR up to 3% at B = 9 T [4]. This work is supported by DAAD 57214224 and DFG Grant SA 3095/2-1. [1] M. W. Barsoum, Prog. Solid State Chem. 28, 201 (2000). [2] A. S. Ingason et al., Mater. Res. Lett. 2, 89-93 (2014). [3] R. Salikhov, et al. J. Appl. Phys. 121, 163904 (2017). [4] Iu. P. Novoselova, et al. (under review).

MA 4.9 Mon 11:45 EB 202

The complex electronic phase diagram of single-crystalline R_2PdSi_3 (R = Ho, Dy) studied by thermal expansion and magnetostriction — •Liran Wang[1], Binh Tran[1], Mingquan He[2], Christoph Meingast[2], Mahmoud Abdel-Hafiez[3], Chongde Cao[4], Jens Bitterlich[5], Wolfgang Löser[5], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute of Physics, Heidelberg University, Germany — [2]Institute for Solid State Physics, Karlsruhe Institute of Technology, Germany — [3]Physikalisches Institute Goethe-Universität,Germany — [4]Department of Applied Physics, Northwestern Polytechnical University, P.R. China — [5]Leibniz Institute for Solid State and Materials Research IFW Dresden, Germany

Thermal expansion and magnetostriction of single-crystalline R_2PdSi_3 (R=Ho,Dy) have been investigated by means of high-precision capacitance dilatometry and by specific heat studies. Pronounced anomalies in the uniaxial thermal expansion coefficients α_a and α_c and in the specific heat c_p mark the onset of long-range AFM order. The different nature of the ground states in both materials is concluded from signs of the thermal expansion anomalies, i.e., opposite uniaxial pressure dependencies. In both materials, there are Schottky-like anomalous entropy and anisotropic length changes which are attributed to crystal field effects and reorientation of the easy magnetic axes. The low-T magnetic phase diagrams and the magnetostriction data imply an interplay of single-ion effects and magnetic exchange interaction. Even small magnetic fields yield ferrimagnetic phases via yet unknown intermediate AFM (Dy_2PdSi_3) and ferrimagnetic (Ho_2PdSi_3) phases.

MA 4.10 Mon 12:00 EB 202

Symmetry and Spin Reorientation in Low-Dimensional Antiferromagnet $SeCuO_3$ — •Mirta Herak[1], Nikolina Novosel[1], William Lafargue-dit-Hauret[2], Xavier Rocquefelte[2], Željko Rapljenović[1], Martina Dragičević[1], and Helmuth Berger[3] — [1]Institute of Physics, Bijenička c. 46, HR-10000 Zagreb, Croatia — [2]Institut des Sciences Chimiques de Rennes UMR 6226, Université de Rennes 1, 35042 Rennes Cedex, France — [3]École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

We study the antiferomagnetic ground state of low-dimensional $SeCuO_3$ by combining torque magnetometry with simple phenomenological approach to magnetic anisotropy and Density Functional Theory (DFT) calculations. Combining measured torque data with phenomenological approach allows us to choose between several symmetry allowed shapes of magnetic anisotropy energy (MAE) and to determine spin orientation in zero and finite magnetic field. Results obtained in magnetic fields larger than spin-flop field indicate that spin reorientation is more complicated than usual spin flop found in collinear antiferromagnet. The microscopic origin of MAE in $SeCuO_3$ was also investigated theoretically, based on DFT+U calculations including spin-orbit coupling on an antiferromagnetic model. It was evidenced inequivalent copper sites impact differently the magnetic anisotropy of this system, leading to a change of the easy magnetization axis. This work is fully supported by the HrZZ grant UIP-2014-09-9775 and by the COGITO project "Theoretical and experimental study of magnetic and multiferroic materials".

MA 4.11 Mon 12:15 EB 202

Higgs mode and its decay in a two-dimensional antiferromagnet — Anil Jain[1,2], •Maximilian Krautloher[1], Juan Porras[1], Gihun Ryu[1], D.P. Chen[1], Douglas Abernathy[3], Jitae Park[4], Alexandre Ivanov[5], Jiri Chaloupka[6], Giniyat Khaliullin[1], Bernhard Keimer[1], and B.J. Kim[1,7] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]Solid State Physics Division, Bhabha Atomic Research Centre, Mumbai — [3]Quantum Condensed Matter Division, ORNL — [4]Heinz Maier-Leibnitz Zentrum, TU München — [5]Institut Laue-Langevin, Grenoble — [6]Central European Institute of Technology, Masaryk University, Kotlářská — [7]Department of Physics, Pohang University of Science and Technology

In recent years significant research has focused upon emergent behavior arising from a convergence of spin-orbit coupling (SOC) and strongly correlated electron interaction energies in $4d$ and $5d$-electron transition metal oxides. We have concentrated our investigation on Ca_2RuO_4, a layered 2D antiferromagnet. Mixing of the cubic crystal field and SOC results in a nominally non-magnetic pseudospin $\tilde{J} = 0$ state, which contrasts with experimental findings. To resolve this issue G. Khaliullin (PRL **111**, 197201 (2013)) proposed a mechanism where magnetically active transitions between the $\tilde{J} = 0$ singlet and higher energy $\tilde{J} = 1$ triplet are enabled by virtue of superexchange interactions, resulting in *excitonic magnetic* order. Here we present inelastic neutron scattering results that illustrate a key signature of this ground state – the presence of a longitudinal mode (or Higgs mode) that corresponds to length fluctuations of $\tilde{J}$.

MA 4.12 Mon 12:30 EB 202

Time-resolved nuclear resonance scattering experiments on spin crossover complexes — •Sakshath Sadashivaiah[1], Kevin Jenni[1], Andreas Omlor[1], Christina-Sophie Müller[1], Lena Scherthan[1], Marcus Herlitschke[2], Ilya Sergeev[2], Hans-Christian Wille[2], Ralf Röhlsberger[2], Juliusz Wolny[1], and Volker Schünemann[1] — [1]Department of Physics, University of Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Deutsches Elektronen synchrotron (DESY), 22607 Hamburg, Germany

The high spin (HS) - low spin (LS) phase transition in laser excited spin crossover complexes occurs though an intermediate state of cooperative lattice vibrations. The mechanism is debated because the phonon density of states (DOS) is only partially accessed in previous studies such as Raman scattering or reflectivity [1]. Through time-resolved Nuclear Inelastic Scattering (NIS) experiments, we study the full DOS of the ground and excited states at 100 K in the [Fe(PM-BIA)$_2$(NCS)$_2$] complex using 14.4 keV synchrotron radiation (SR) pulses. The sample was excited by time-delayed laser pulses derived from a 531 nm source, which was triggered at every alternate SR pulse. By performing NIS (and Nuclear forward scattering) using the SR pulses accompanying the laser pulses, we measured the excited state [2]. The alternate SR pulses probe the ground state. We follow the effect of the laser pulses by comparing the resulting spectra with the static HS and LS spectra.

[1] R. Bertoni et al, *Nat. Mater.* **15**, 606 (2016).
[2] S. Sakshath et al, *Hyperfine Interact.* **238**, 89 (2017)

MA 5: Heusler compounds, semimetals and oxides (joint session MA/TT)

Time: Monday 9:30–13:15 Location: EB 301

MA 5.1 Mon 9:30 EB 301

Epitaxial growth of compensated ferrimagnetic Heusler thin films Mn-Fe-V-Al — •Siham Ouardi, Kazuya Z. Suzuki, and Shigemi Mizukami — WPI Advanced Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan

Cubic Heusler compound $Mn_{1.5}FeV_{0.5}Al$ is a fully compensated half-metallic ferrimagnet with 24 valence electrons per formula unit. Here we report on epitaxial growth of the compensated ferrimagnetic Mn-Fe-V-Al Heusler films. The thin films of 30 nm thickness were grown directly on single crystalline MgO (001) substrates by using an ultra-high-vacuum magnetron sputtering technique. The Heusler structure was characterized by x-ray diffraction. The crystal structure ordering was controlled by the deposition at various substrate temperatures. Magnetometry measurements show a nearly vanishing magnetization where the anomalous Hall measurements exhibited magnetic ordering. The ferrimagnetic coupling between the different sublattices (Mn, Fe, and V) will discussed based on magnetic dichroism in angle-resolved hard X-ray photoelectron spectroscopy (MCD-HAXPES). The advantage of vanishing magnetization in combination with high spin polarization of this material thin films provides the possibility for spintronic device applications.

This work is supported by the Grant-in-Aid for Scientific Research KAKENHI (17H06513).

MA 5.2 Mon 9:45 EB 301

Polycrystalline vs Epitaxial Fe2-xMn1+xAl Heusler films with exchange bias shift — •Samer Kurdi[1], Giorgio Divitini[1], Massimo Ghidini[1,2,3], Markus Meinert[4], Marco Coïsson[5], Thomas Forrest[3], Günter Reiss[4], Sarnjeet Dhesi[3], Paola Tiberto[5], and Zoe Barber[1] — [1]University of Cambridge, UK — [2]Department of Physics, University of Parma, Italy — [3]Diamond Light Source, Oxfordshire, UK — [4]Center for Spinelectronic Materials and Devices, Bielefeld University, Germany — [5]INRIM, Torino, Italy

Magnetic recording devices are pervasive in current technology, and the development of environmentally friendly, sustainable and scalable devices based on Earth-abundant materials is a high research priority. In this study we investigate a simple, cost-effective single-layer exchange biased film for spin valves, a fundamental part of data storage systems.

We grew 200 nm polycrystalline and epitaxial Fe2-xMn1+xAl (x = -0.25, 0, 0.25) Heusler alloy films and characterized them to study the influence of Mn content on the exchange bias shift. The microstructure is shown to have a profound effect on film properties. In-situ annealing

TEM studies show that the polycrystalline samples have Mn-rich and Fe-rich phases inducing a spin glass exchange bias shift of around 150 Oe at 4 K for Fe1.75Mn1.25Al. The exchange bias shift was observed at temperatures up to 12 K for the Fe1.75Mn1.25Al and up to 6 K for Fe2MnAl polycrystalline samples, whilst only the Fe1.75Mn1.25Al epitaxial film showed any bias shift (50 Oe, below 2 K). XMCD sum rule analysis of the polycrystalline samples showed different behaviour from the as-predicted perfectly ordered L21 Heusler structure.

MA 5.3 Mon 10:00 EB 301

Evolution of the interfacial perpendicular magnetic anisotropy constant of the Co_2FeAl interface upon annealing — •Andres Conca[1], Alessia Niesen[2], Guenter Reiss[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Center for Spintronic Materials and Devices, Physics Department, Bielefeld University, 33615 Bielefeld, Germany

We investigate a series of films with different thicknesses of the Heusler alloy Co_2FeAl in order to study the effect of annealing on the interface with a MgO layer and on the bulk magnetic properties. Our results reveal that while the perpendicular interface anisotropy constant $K_S^{\perp}$ is zero for the as-deposited samples, its value increases with annealing up to a value of 1.14 ± 0.07 mJ/m^2 for the series annealed at 320°C and of 2.0 ± 0.7 mJ/m^2 for the 450°C annealed series owing to a strong modification of the interface during the thermal treatment. This large value ensures a stabilization of a perpendicular magnetization orientation for a thickness below 1.7 nm. The data additionally shows that the in-plane biaxial anisotropy constant has a different evolution with thickness in as-deposited and annealed systems. The Gilbert damping parameter α shows an absolute minimum value of $2.8 \pm 0.1 \times 10^{-3}$. The thickness dependence is explained in terms of an inhomogeneous magnetization state generated by the interplay between the different anisotropies of the system and by the crystalline disorder.

Support by M-era.Net and HEUMEM is acknowledged.

MA 5.4 Mon 10:15 EB 301

high throughput screening for 3D spin gapless semiconductors in Heusler compounds — •qiang gao, ingo ophale, and hongbin zhang — Institute of Materials Science, TU Darmstadt, Darmstadt, Germany

In recent years, spin-gapless semiconductors (SGSs) have drawn intensive attention to the spintronics community. SGSs are half metals with the valence band maximum and conduction band minimum touching each other directly or indirectly (1). In this work, we performed high throughput screening for novel three-dimensional SGSs in quaternary Heusler compounds. Following the empirical rule, we focused on compounds with 18, 21 or 26 valence electrons (2). We have found many new Heusler compounds as candidate SGSs, with both direct and indirect touching. In particular, it is observed that spin-orbit coupling can also drive some systems into the SGS phase, resulting in possible interesting applications for future spintronic devices. (1) X.L. Wang, Phys. Rev. Lett., **100**, 156404 (2008). (2) X.T. Wang, Z.X. Cheng, J.L. Wang, X.L. Wang, G.D. Liu, J. Mater. Chem. C, **4**, 7176-7192 (2016).

MA 5.5 Mon 10:30 EB 301

Symmetry and magnitude of intrinsic spin-orbit torques in the half-Heusler alloy PtMnSb — •Johannes Mendil[1], Jan Krieft[2], Phuong Dao[1], Can Onur Avci[1], Myriam Haydee Aguirre[3], Karsten Rott[2], Jan-Michael Schmalhorst[2], Frank Freimuth[4], Günter Reiss[2], Timo Kuschel[2], and Pietro Gambardella[1] — [1]Department of Materials, ETH Zürich — [2]CSMD, Department of Physics, Bielefeld University — [3]Universidad de Zaragoza — [4]Peter Grünberg Institut, FZ Jülich

Magnetization manipulation by spin-orbit torques (SOTs) has advanced to an active research field over the past few years and is mostly focused on conventional ferromagnets deposited on heavy metal layers where the space inversion symmetry is broken at the interface[1]. However, space inversion symmetry is intrinsically broken in noncentrosymmetric crystals [2]. We present the first observation of intrinsic SOTs in PtMnSb single layers, which is a magnetic half-Heusler alloy. It was prepared by co-sputtering [3]. Using crystallographic symmetry, we separate the observed SOTs in odd and even components with respect to magnetization inversion. We reveal corresponding effective fields that scale up to the 2nd and 3rd power of magnetization components with a distinct symmetry compared to standard field-like and damping-like SOTs. Finally, we characterize the SOTs as a function of PtMnSb thickness and discuss the possibility of using PtMnSb for magnetic switching applications. [1] Garello et al., Nat. Nanotech. 8, 587 (2013) [2] Ciccarelli et al., Nat. Phys. 12, 855 (2016) [3] Krieft, Mendil et al., Phys. Stat. Sol. (RRL) 11, 1600439 (2017)

MA 5.6 Mon 10:45 EB 301

Electrical transport in the tetragonal Heusler system Mn-Pt-Ga — •Vivek Kumar[1], Ajaya K. Nayak[2], Nitesh Kumar[1], Peter Adler[1], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]National Institute of Science Education and Research Bhubaneswar, Jatni, India

Nontrivial magnetic textures have attracted interest for improving desired properties in spintronic devices. Materials with noncentrosymmetric crystal structure are capable of inducing nontrivial spin structures due to the presence of Dzyaloshinskii-Moriya interaction (DMI). We have recently reported the magnetic antiskyrmions in tetragonal Heusler material $Mn_{1.4}Pt_{0.9}Pd_{0.1}Sn$ [1]. Here, we present the effect of spin-orbit interaction in another inverse tetragonal Heusler system Mn-Pt-Ga by electrical transport measurements. The tetragonal Mn_3Ga has ferrimagnetic order where Mn atoms sit on two different magnetic sublattices. The substitution of a late transition metal in place of Mn, here Pt, leads to breaking the inversion symmetry [2]. We found an anomaly in Hall resistivity which is dominating at higher Pt substitution. The behavior of Hall resistivity cannot be scaled with magnetization. This is an indication of non-coplaner spin configurations in this system which are stabilized due to increase in DMI.

[1]A. K. Nayak *et al.*, Nature **548**, 561 (2017).

[2]S. Chadov *et al.*, Phys. Rev. B **91**, 094203 (2015).

MA 5.7 Mon 11:00 EB 301

Physical properties of the CuMnAs alloy - promising material for the antiferromagnetic spintronics — •Frantisek Maca[1], Josef Kudrnovsky[1], Vaclav Drchal[1], Karel Carva[2], Pavel Balaz[2], and Ilja Turek[2] — [1]Institute of Physics ASCR, Praha — [2]Faculty of Mathematics and Physics, Charles University, Praha

We have investigated from first principles the role of defects in the antiferromagnetic CuMnAs alloy with tetragonal structure [1]. Mn_{Cu}, Cu_{Mn}, Mn-Cu swaps, and vacancies on Mn- and Cu-sublattices are the most probable defects in this material. We have found that the electron correlations play important role in description of the phase stability.

We calculated transport properties for CuMnAs with defects of low formation energies and estimated in-plane resistivity of CuMnAs. Our numerical simulations fitted experiment very well if we assumed concentrations 3.5-5% Mn_{Cu} or Mn-Cu swaps, much larger concentrations would be needed for Cu_{Mn} defects or Mn-vacancies. We have estimated also the Neel temperature using the Monte Carlo approach, result agrees reasonably well with the experimentally observed value.

[1] F. Máca, J. Kudrnovský, V. Drchal, K. Carva, P. Baláž, and I. Turek, Phys. Rev. B **96** (2017) 094406.

15 minutes break

MA 5.8 Mon 11:30 EB 301

Improved reversibility by hydrostatic pressure in Ni-Mn based Heusler alloys — •Parul Devi[1], Luana Caron[1], Sanjay Singh[1], Alexandre Magnuu G. Carvalho[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Laboratório Nacional de Luz Síncrotron, SáoPaulo, Brasil

Ni-Mn based Heusler alloys show first order diffusionless magnetostructural phase transition. The first order magnetostructural phase transition results in large magnetocaloric effect due to the change in both magnetic and crystal structure. The thermal or magnetic hysteresis is characteristic of first order phase transition which results in irreversibility of MCE. This irreversibility makes these materials less efficient for magnetic refrigeration. Therefore, nowadays, a lot of efforts have been made to reduce the hysteresis in these alloys [1]. In the present work, we observed a large reduction of hysteresis in off stoichiometric composition of Ni-Mn-In by hydrostatic pressure. To confirm that it is applicable to all Heusler alloys, we did it for two more different compositions of Ni-Mn based Heusler alloys. We got the decrement of hysteresis in these materials as well. However the rate of decrease in all three materials were different. Furthermore, we confirmed that the decrease in hysteresis was because of the increasingly geometric compatibility condition, recently predicted by James and co-workers [2].

[1]J. Liu *et al.*, Nature materials **11**, 620 (2012).
[2]Y. Song *et al.*, Nature Letter **502**, 85 (2013).

MA 5.9 Mon 11:45 EB 301

NMR investigations of irradiation-induced structural changes in Co_2MnSi thin films — •Franziska Hammerath[1], Mira R. D. Brandt[1], Rantej Bali[2], Kay Potzger[2], Roman Böttger[2], Rene Hübner[2], Yuya Sakuraba[3], Bernd Büchner[1], and Sabine Wurmehl[1] — [1]IFW Dresden, Institute for Solid State Research, Helmholtzstraße 20, 01069 Dresden — [2]Institute of Ion Beam Physics and Materials Research, HZDR, Bautzner Straße 400, 01328 Dresden, Germany — [3]National Institute for Materials Science (NIMS), Sengen 1-2-1, Tsukuba, Ibaraki 305-0047, Japan

Co_2MnSi is a well-known Heusler compound which is predicted to be half-metallic, i.e., possessing 100% spin-polarization and, thus, being a promising candidate material for enhancing the magneto-resistance of spin-valves [1]. Half-metallicity depends sensitively on the local chemical order, hence methods to improve the structure of Co_2MnSi towards the ideal $L2_1$ order and, thus, to achieve full spin-polarization are of huge technological relevance. On the basis of XRD measurements it has been argued that irradiation with He^+ ions induces an improvement of B2-order in Co_2MnSi thin films towards a possible formation of $L2_1$ order [2]. We investigated the structure-property relationship of He^+-irradiated Co_2MnSi alloy thin films locally by means of ^{59}Co nuclear magnetic resonance (NMR) and observed an increased disorder upon increasing the ion flux, going along with a decrease of the saturation magnetization.

[1] T. Iwase *et al.*, Appl. Phys. Express **2**, 063003 (2009).
[2] O. Gaier *et al.*, Appl. Phys. Lett. **94**, 152508 (2009).

MA 5.10 Mon 12:00 EB 301

Optical properties of pyrochlore iridates: signatures of electron correlation and spin-orbit-lattice coupling — •Alexander Boris[1], Alexander Yaresko[1], Timofei Larkin[1], Ksenia Rabinovich[1], Aleksandra Krajewska[1,2], Tomohiro Takayama[1,2], Hidenori Takagi[1,2], and Bernhard Keimer[1] — [1]Max Planck Institute for Solid State Research, Stuttgart, Germany — [2]University of Stuttgart, Stuttgart, Germany

Spectroscopic ellipsometry is used to determine the dielectric function of $A_2Ir_2O_7$ ($A = In, Lu, Y$) polycrystalline samples in the wide spectral range from 10 meV to 6.5 eV at temperatures from 7 K to 300 K. Comparing the spectra with the results of relativistic LSDA+U band structure calculations, we quantitatively classify pyrochlore $A_2Ir_2O_7$ as spin-orbital $J_{eff} = 1/2$ Mott insulators with the on-site Coulomb interaction $U \approx 1.5$ eV and electronic bandwidths $W = 0.3 \div 0.5$ eV. Exciton doublets with pronounced Fano line shapes were identified in $Y_2Ir_2O_7$ and $Lu_2Ir_2O_7$ upon cooling below the magnetic ordering temperatures $T_N = 150$ K and 145 K, respectively. Our results indicate considerable effects of long-range Coulomb interaction and spin-orbit-lattice coupling in the 5d pyrochlore compounds and the need for a detailed analysis of their influence on the $J_{eff} = 1/2$ states. Newly synthesized $In_2Ir_2O_7$ does not exhibit the absorption edge and phonon anomalies below $T_N = 45$ K and thus serves as a reference.

MA 5.11 Mon 12:15 EB 301

Anisotropy of the spin-fluctuations and its impact on the symmetry of the order parameter in the unconventional Sr2RuO4 superconductor. — S. Khmelevskyi[1], B. Kim[2], D. D. F. Agterberg[3], P. Mohn[1], •I. I. Mazin[4], and C. Franchini[2] — [1]Center for Computational Materials Science, Vienna University of Technology, Vienna, Austria — [2]Center for Computational Materials Physics, Vienna University, Vienna, Austria — [3]University of Wisconsin, Milwaukee, USA. — [4]Naval Research Laboratory, Washington DC, USA.

The superconductivity (SC) in the Sr2RuO4 has attracted a considerable interest in the past two decades comparable to that in cuprates and iron pnictides. NMR experiments strongly suggested a triplet chiral order parameter, while more recent probes of strained crystals point toward singlet pairing. In this work the structure of the spin-fluctuations in the Sr2RuO4 has been investigated from first principles using the DLM formalism and Lichtenstein method. We find that IC spin-fluctuations are stabilized but several magnetic ground states with q close to the commensurate (1/3, 1/3, 0) value are degenerate. We show that the degeneration is removed by Spin-orbit coupling and a very special collinear modulated magnetic structure with periodicity 1/3 is stabilized in the mean field in the [110] direction. We show that anisotropic magnetic terms provide an energy penalty for rotating the order parameter that is several orders of magnitude too large for the accepted interpretation, thus rendering the NMR experiment completely inexplicable in terms of the conventional theory.

MA 5.12 Mon 12:30 EB 301

Magnetic shape-memory effect in $SrRuO_3$ — •Daniel Brüning[1], Stefan Kunkemöller[1], Agung Nugroho[2], Isabelle Stunault[3], Markus Braden[1], and Thomas Lorenz[1] — [1]II. Physikalisches Institut, Universität zu Köln, Germany — [2]Faculty of Mathematics and Natural Science, Institut Teknologi Bandung, Indonesia — [3]Institut Laue Langevin, Grenoble, France

As most perovskites, $SrRuO_3$ exhibits structural phase transitions associated with rotations of the RuO_6 octahedra. From a high temperature cubic phase it becomes tetragonal at 975 K and orthorhombic at 800 K resulting in six possible domains. Furthermore, $SrRuO_3$ orders ferromagnetically at $T_c = 160$ K with easy axis anisotropy due to spin orbit coupling. Our neutron diffraction and macroscopic measurements unambiguously show that magnetic fields rearrange structural domains, although the ferromagnetic order occurs at six times lower temperature than the structural distortion. For the field along a cubic $[110]_c$ direction, a fully detwinned crystal is obtained. Subsequent heating above T_c causes a magnetic shape-memory effect, where the initial structural domains recover, which is similar to Heusler alloys.

Kunkemöller *et al.*, arXiv:1709.05688 (2017)

Funded by the DFG via CRC 1238 Projects A02, B01, and B04.

MA 5.13 Mon 12:45 EB 301

Multicritical Lifshitz transition of the Fermi-surface in $Sr_3Ru_2O_7$ — •Joseph Betouras[1], Dmitry Efremov[1,2], Alex Shtyk[3], Andreas Rost[4], Claudio Chamon[5], and Andrew Mackenzie[4,6] — [1]Department of Physics, Loughborough University, Loughborough, UK — [2]Leibniz-Institut fur Festkorper- und Werkstoffforschung, D-01069 Dresden, Germany — [3]Department of Physics, Harvard University, Cambridge, MA 02138, USA — [4]SUPA, School of Physics and Astronomy, University of St. Andrews, St. Andrews KY16 9SS, U.K. — [5]Department of Physics, Boston University, Boston, MA, 02215, USA — [6]Max Planck Institute for Chemical Physics of Solids, Noethnitzer Str. 40, 01187 Dresden, Germany

We present a theoretical framework, supported by experimental evidence for a Lifshitz topological transition of the Fermi surface in the ultra-clean layered perovskite metal $Sr_3Ru_2O_7$ [1]. Strong power-law dependence of the density of states on energy, associated to the topological transition, in addition to other main features of the Fermi surface as well as interactions, can lead to novel physics. As a consequence, many yet unexplained properties of the thermodynamics and formation of phases of this material can be understood. In particular, we naturally explain the increase of the entropy[2] as well as the formation of spin density wave (phase A) [3]. This work provides an example of the power of Fermi surface topological transitions.

[1]S. A. Grigera, S. A. et al. Science 306, 1154 (2004).
[2] A. Rost et al., Science 325, 1360 (2009).
[3] C. Lester et al, Nature Materials 14, 373 (2014).

MA 5.14 Mon 13:00 EB 301

Study of reorientation in $NdFe_{0.5}Mn_{0.5}O_3$ — Ankita Singh[1], Anil Jain[2], Avijeet Ray[1], Vivian Nassif[3], Tulika Maitra[1], and •Vivek K. Malik[1] — [1]Department of Physics, IIT Roorkee, Roorkee, 247667, India — [2]Solid State Physics Division, Bhabha Atomic Research Center, Mumbai 400085, India — [3]Institut Laue -Langevin, 71 Avenue des Martyrs, 38000 Grenoble, cedex 9 France

In the present study, we have studied spin reorientation in $NdFe_{0.5}Mn_{0.5}O_3$ using neutron powder diffraction technique. Polycrystalline compound $NdFe_{0.5}Mn_{0.5}O_3$ was synthesized using the standard solid state reaction method. Neutron powder diffraction experiments over the temperature range of 1.5-300 K have been performed. Our neutron diffraction study shows that below the Néel temperature (T_N250 K), the magnetic structure (for the Fe/Mn spins) is a G-type antiferromagnet [corresponding to the Γ_1 representation with spins aligned along the crystallographic b direction. Below 70 K, additional peaks appear in the neutron diffraction pattern. Rietveld refinement (below 70 K) confirms a coexistence of two magnetic phases corresponding to representations Γ_1 and Γ_2. In the magnetic structure corresponding to the Γ_2 representation, Fe/Mn spins are aligned along the crystallographic c direction (with small ferromagnetic component along the crystallographic a axis). Upon cooling (below 50 K), the phase fraction of the second magnetic phase increases. At 1.5 K, magnetic structure can be described only by Γ_2 representation. An antisymmetric exchange interaction between R^{3+}-Mn^{3+}/Fe^{3+}spins might be responsible for the observed spin reorientation.

MA 6: Ultrafast magnetism I

Time: Monday 9:30–12:45 Location: EB 407

MA 6.1 Mon 9:30 EB 407

Manipulation of magnetic order in antiferromagnets — •Fabian Mertens, Marc Terschanski, Stefano Ponzoni, Davide Bossini, and Mirko Cinchetti — Experimentelle Physik VI, TU Dortmund, Otto-Hahn-Straße 4, 44227 Dortmund, Germany

The spin dynamics in antiferromagnetic materials is intrinsically fast compared to other magnetic materials, making antiferromagnets interesting for possible future applications like faster data storage. In this talk, we present the magneto-optical setup that was recently built in our group to study the ultrafast optical manipulation of the magnetic order in antiferromagnets. The setup is based on a femtosecond laser with repetition rates of up to 1 MHz, coupled to two optical parametic amplifiers (OPA) for the independent tuning of the pump and the probe beam to photon energies between 0.5 eV up to 3.5 eV. The problem of single pulse detection at high repetition rates was solved by a home-built balanced photodetector. We will present the characterization of the home-built detector and the first experimental results optained with the setup.

MA 6.2 Mon 9:45 EB 407

Optically induced symmetry breaking in multiferroic h-$YMnO_3$ probed by second harmonic generation — •Christian Tzschaschel[1], Mads Weber[1], Manfred Fiebig[1], and Takuya Satoh[2,3] — [1]ETH Zürich, Switzerland — [2]The University of Tokyo, Japan — [3]Kyushu University, Japan

Recent advances in antiferromagnetic spintronics demand for a better understanding of the order-parameter dynamics on ultrafast time scales. Here, we demonstrate an optically induced coherent modulation of the antiferromagnetic (AFM) order parameter in the multiferroic phase of hexagonal $YMnO_3$. We employ optical second harmonic generation (SHG) as a highly symmetry sensitive probe that couples directly to the AFM order. Exploiting the inverse Faraday effect (IFE), we optically induce a spin precession, which transiently reduces the symmetry of the magnetic lattice from $\underline{6}m\underline{m}$ to 3. Probing the symmetry of the magnetic lattice by SHG, we observe a periodic anisotropy modulation. The periodicity corresponds to a magnon mode in $YMnO_3$. This is further verified by simultaneous measurements of the transiently occuring Faraday rotation. The observed SHG modulation and the Faraday rotation can be described by a combined model of the microscopic spin system with a phenomenological description of the IFE. This model furthermore allows us to directly extract the basal plane spin rotation angle from the SHG data – a quantity that is hardly accessible by established magneto-optical techniques.

MA 6.3 Mon 10:00 EB 407

Ultrafast dynamics of Néel vector in aniferromagnetic thin films detected with optical pump probe spectroscopy — •Vladimir Grigorev[1,2], Alexey Sapozhnik[1,2], Stanislav Bodnar[1], Martin Jordn[1], and Jure Demsar[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Mainz, Germany — [2]Graduate School of Excellence, Materials Science in Mainz (MAINZ), Mainz, Germany

Determination of the Néel vector in an antiferromagnetic (AFM) thin film is not trivial and usually requires large-scale facilities. Recently a novel method was demonstrated, utilizing the modulation aspect of the optical pump-probe technique [P. Saidl, et al., Nature Photonics 11, 91-97 (2017)]. We applied this method to determine the Néel vector in the c-axis oriented Mn2Au thin films. Analysis of angular dependence of the pump induced polarization rotation clearly suggests the Néel vector to be pointing along the <110> crystallographic direction, in agreement with recent experimental studies on bulk samples and theoretical calculations. Moreover, following the time evolution of the angular dependent polarization rotation, we were able to resolve the photoinduced rotation of the Néel vector and its recovery on the 100 picosecond timescale. The observed photoinduced rotation proceeds on the 5 ps timescale, which is in a good agreement with the characteristic time of strain induced expansion of the thin film. This suggests a strong coupling of the magnetic order to crystal lattice.

MA 6.4 Mon 10:15 EB 407

Computational investigation of ultrafast magnetization dynamics; ferromagnets vs antiferromagnets — •Unai Atxitia[1], Severin Selzer[2], Tobias Birk[2], Marcel Strohmeier[2], and Ulrich Nowak[2] — [1]Department of Physics, Freie Universität Berlin, D-14195 Berlin, Germany — [2]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

The speed of switching between two stable magnetic states has become a major bottleneck for future advancement of magnetic-based information technologies. Magnetization dynamics in antiferromagnets (AFM) are proposed to be considerably faster than their ferromagnetic (FM) counterparts. In FM, thermal effects can drive magnetization dynamics in a wide range of timescales, from femtosecond laser induced subpicosecond magnetic order relaxation to the slower thermally activated magnetic reversal in nanoparticles. Thermally induced magnetization dynamics in AFM are rather unknown. Here, we investigate the differences between AFM and FM in the thermally induced magnetization dynamics by means of computer simulations based in atomistic spin models. First, we investigate the superparamagnetic limit. Surprisingly, we find that in AFM nanoparticles, switching time is faster than in FM, even if the energy barrier is the same. Second, sub-picosecond heat induced demagnetization; in AFM is up to one order of magnitude faster than in FM. Interestingly, the subsequent remagnetization process to the initial state could also be up to two orders of magnitude faster than in FM. These findings have strong implications for ultrafast control of magnetic states in antiferromagnets.

MA 6.5 Mon 10:30 EB 407

Ultrafast magnetization and lattice dynamics: non-thermal effects — •Karel Carva[1], Pablo Maldonado[2], Pavel Balaz[1], and Peter M. Oppeneer[2] — [1]Charles University, DCMP, Ke Karlovu 5, CZ-12116, Prague, Czech Republic — [2]Uppsala University, PO Box 516, 75120 Uppsala, Sweden

Femtosecond lasers allow to observe magnetization dynamics on an unprecedently short timescale. This dynamics is often described employing the three temperature model, without verifying its validity.

Here we study magnetization dynamics with a special emphasis to non-thermal effects. We have calculated electron-phonon scattering rates for systems with a high electronic temperature, and phonon lifetimes due to phonon-phonon scattering. From these we obtain phonon populations that differ sharply from the thermal ones within picoseconds after the pump [1]. This allows us to understand recent experimental observations and disproves the applicability of the model based on one lattice temperature here [2].

Another important consequence of ultrafast demagnetization is the presence of spin currents described by the superdiffusive spin transport model [3]. This is also a non-thermal effect since electrons with energy significantly above the Fermi level play crucial role there. We compare it to its thermal counterpart, the spin-dependent Seebeck effect.

[1] P. Maldonado et al., Phys. Rev. B 96, 174439 (2017)
[2] T. Henighan et al., Phys. Rev. B 93, 22030 (2016)
[3] M. Battiato et al., Phys. Rev. Lett. 105, 027203 (2010)

15 minutes break

MA 6.6 Mon 11:00 EB 407

Ultra-fast control of the magnetic order of materials by laser light — •Sangeeta Sharma[1], John Kay Dewhurst[1], Peter Elliott[1], Sam Shallcross[2], and E. K. U. Gross[1] — [1]Max Planck Inst. of micro structure physics, Halle, Germany — [2]Lehrstuhl fuer Theoretische Festkoerperphysik, Erlangen University, Erlangen, Germany

By creating via pump laser pulse a non-equilibrium distribution of charge on sub-exchange time scales (i.e., faster than the time scale associated with spin flip in the ground state) we demonstrate that a precise control of magnetic structure is possible on ultra-short time scales, including switching of spin order from anti-ferromagnetic (AFM) to transient ferromagnetic (FM). The microscopic physics of this ultrafast spin modulation is dominated by charge flows created by spin-preserving optical excitations, one of the fastest means of manipulating an electronic system by light. We demonstrate this mechanism to be universally applicable to AFM, FM, multilayers and bulk systems, and provide three rules that encapsulate the laser induced early time magnetization dynamics of multi-sub-lattice systems.

MA 6.7 Mon 11:15 EB 407

Localized-spin dynamics from time-dependent correlation functions — •Kai Leckron and Hans Christian Schneider — University of Kaiserslautern, Department of Physics

We present a microscopic method for the calculation of spin dynamics in Heisenberg models with coupling to a phonon bath using time-dependent correlation functions. We discuss the general strategy to truncate the hierarchy of equations of motion and to obtain approximations at a given level of spin correlations. In this talk, we use an approximation scheme that is exact for the case of a three-spin system. The phonons are treated as a bath in this approach, where contributions of higher order are taken into account using a broadening of the bath interactions.

We apply this method to calculate the spin dynamics after an instantaneous switching of local spins in small ferromagnetically and antiferromagnetically coupled Heisenberg systems and we investigate the influence of the broadening on the magnetization dynamics.

MA 6.8 Mon 11:30 EB 407

A micromagnetic model for ultrafast spin current-driven magnon dynamics — •Henning Ulrichs[1] and Ilya Razdolski[2] — [1]I. Physical Institute, Georg-August University of Göttingen, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [2]Physical Chemistry Department, Fritz Haber Institute of the Max Planck Society, Faradayweg 4-6, 14195 Berlin, Germany

Recent experimental reports have demonstrated that optically induced femtosecond spin currents can excite coherent magnon dynamics in the THz frequency range.[1,2] In this talk I will discuss a simple micromagnetic model for this process. The basic ingredient of this practically 1d model is a Slonczewski-like spin-transfer torque term. With this, we can reproduce the salient features of the experiments presented in reference [1]. Furthermore, the model provides insight into the factors which govern the spin wave mode-specific excitation efficiency. Lastly, I will discuss results for a collinear spin injection geometry. Our modelling shows that then, a thermally occupied magnon ensemble can be heated or cooled on fs time-scales. HU acknowledges financial support by the DFG within project A06 of the SFB 1073.

[1] I. Razdolski et al., Nat. Comm. 8, 15007 (2017)

[2] M.L.M. Lalieu, P.L.J. Helgers, and B. Koopmans, Phys. Rev. B, 96, 014417 (2017)

MA 6.9 Mon 11:45 EB 407

Ultrafast magnetization dynamics probed by Lorentz microscopy — •Marcel Möller[1], John H. Gaida[1], Nara Rubiano da Silva[1], Armin Feist[1], Sascha Schäfer[1,2], and Claus Ropers[1] — [1]4th Physical Institute University of Göttingen, Göttingen, Germany — [2]Physical Institute University of Oldenburg, Oldenburg, Germany

Lorentz microscopy is a widely applied technique for the nanoscale mapping of magnetization structures. Its adaptation to time-resolved imaging offers fascinating prospects for studying ultrafast magnetization dynamics. The Göttingen Ultrafast Transmission Electron Microscope (UTEM) is a newly developed instrument, which allows for studies of ultrafast magnetization and demagnetization dynamics induced by radio-frequency currents or optical pulses. This is facilitated with an electron source which can either deliver a continuous electron beam or electron pulses with a duration down to 200 fs at a 0.6 eV spectral width and a sub-nm focal spot size. In this contribution, we investigate the gyrotropic motion of a magnetic vortex confined within a 20 nm thick 2μm x 2μm permalloy nanoisland. Exciting the magnetic vortex with an in-plane spin current near the resonance frequency of 101MHz, we are able to track the gyration of the vortex core with 20 nm resolution. Furthermore, we investigate the response of the vortex to non-periodic excitations. Using a sinusoidal current pulse which only lasts for a few cycles, we can trace the build-up and relaxation of the vortex gyration, which yields the damping and the spectral characteristics of our sample system.

MA 6.10 Mon 12:00 EB 407

Nonequilibrium melting of spin and orbital-order in the two-band Hubbard model — •Jiajun Li and Martin Eckstein — Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany

We study the dynamics of spin and orbital order after strong non-equilibrium excitation in a two-band Hubbard model, using non-equilibrium dynamical mean field theory. The model features an A-type antiferromagnetic phase with antiferro-orbital ordering in equilibrium. Various charge excitations are created during the strong electric pulse, causing both spin and orbital order to melt dynamically. However, due to strong anisotropy in the hopping of electrons in the ordered phase, the orbital-order defects are easier to create and move than the spin-order defects. Therefore, the antiferromagnetic order typically melts slower than the antiferro-orbital order. In addition, varying Hund's coupling modifies the energy spectrum of the two-electron sector in the local Hilbert space. We demonstrate that this can be utilized to control the relative populations of non-equilibrium excitations and therefore the dynamical melting of order parameters. Our finding reveals the possibility of preparing non-thermal spin and orbital-ordered phases and may lead to a way of simultaneously controlling the order parameters with non-equilibrium techniques.

MA 6.11 Mon 12:15 EB 407

Steering of domain walls in Co/$Fe_{25}Gd_{75}$ bilayers by ultrashort laser pulses — •Yasser A. Shokr[1,2], Mustafa Erkovan[3], Bin Zhang[1], Oliver Sandig[1], Matthias Bernien[1], Ahmet A. Ünal[4], Florian Kronast[4], Umut Parlak[3], Jan Vogel[5], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, 14195 Berlin, Germany — [2]Faculty of Science, Department of Physics, Helwan University, 17119 Cairo, Egypt — [3]Sakarya University, Nanoscience and Nanoenginering Department, 54187 Sakarya, Turkey — [4]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489 Berlin, Germany — [5]CNRS and Université Grenoble Alpes, Institut Néel, 38042 Grenoble, France

Steering magnetic domain walls by light is of high interest. We present a magnetic domain-imaging study by x-ray magnetic circular dichroism photoelectron emission microscopy on a Co/$Fe_{75}Gd_{25}$ bilayer under exposure to single focused ultrashort (100 fs) infrared laser pulses. Magnetic domain walls experience a force in the gradient of the laser pulses away from the center of the pulse, which can be used to move domain walls in a certain direction. Maximum domain-wall displacements close to 1 μm per laser pulse in zero external field are observed. Quantitative estimates show that electronic spin currents from the spin-dependent Seebeck effect are not strong enough to explain the effect, which we thus attribute to the torque exerted by magnons from the spin Seebeck effect that are reflected at the domain wall. The possibility to steer domain walls by ultrashort laser pulses might open new avenues for writing magnetic information.

MA 6.12 Mon 12:30 EB 407

Laser-induced spin currents in nonhomogeneous magnetic systems — •Pavel Baláž[1,2], Karel Carva[1], Pablo Maldonado[3], and Peter M. Oppeneer[3] — [1]Charles University, Faculty of Mathematics and Physics, Department of Condensed Matter Physics, Ke Karlovu 5, CZ 121 16 Prague, Czech Republic — [2]IT4Innovations Center, VSB-TU Ostrava, 17.listopadu 15, CZ 70833 Ostrava, Czech Republic — [3]Uppsala University, Dept. of Physics and Astronomy, Box 530, S-751 21 Uppsala, Sweden

Laser-induced ultrafast demagnetization of transition metals and their alloys is accompanied by generation of spin current of hot electrons which diffuses along the sample. This process is well described by superdiffusive spin transport, which can be applied to a multilayer structure consisted of ferromagnetic (F) and nonmagnetic (N) metallic layers [1]. Recently, a model of spin transfer torque for a F/N/F trilayer with perpendicular magnetizations has been developed [2].

Here, laser-induced processes in magnetic textures like domain walls shall be studied. First, we shall analyze how ultrafast demagnetization influences the domain wall structure. Second, we shall study how spin currents arise in the vicinity of the spin texture.

[1] M. Battiato, K. Carva, P. Oppeneer Phys. Rev. Lett. 105, 027203 (2010).

[2] P. Baláž, M. Žonda, K. Carva, P. Maldonado, P. M. Oppeneer, arXiv:1710.02083 [cond-mat.mes-hall] (2017).

MA 7: Focus Session: Magnetism in Materials Science: Thermodynamics, Kinetics and Defects I (joint session MM/MA)

Sessions: Magnetism I and Magnetism II

EPS-Symposium organized by Chuchun Fu (CEA-Saclay, Gif-sur-Yvette, France), Thomas Hammerschmidt (Ruhr-Universität Bochum, Germany), Tilmann Hickel (MPI Eisenforschung, Düsseldorf, Germany), and Véronique Pierron-Bohnes (IPCMS CNRS-Unistra, Strasbourg, France).

Time: Monday 10:15–13:15 Location: TC 010

Topical Talk MA 7.1 Mon 10:15 TC 010

First principles many-body calculations for rare earth-based materials: present status and open challenges — •Silke Biermann — Centre de Physique Theorique, Ecole Polytechnique, 91128 Palaiseau, France

Rare earth compounds are at the heart of a wide range of modern materials applications, ranging from permanent magnets to pigments, and reliable and efficient first principles descriptions of their properties are highly desirable in view of the development of rational design techniques. Strong local Coulomb interactions on the rare earth f-shell, however, make ab initio calculations for such materials challenging.

We will review the present status of dynamical mean field theory-based approaches to the problem and describe recent methodological developments in the field [1,2,3].

[1] P. Seth, P. Hansmann, A. van Roekeghem, L. Vaugier, S. Biermann, Physical Review Letters 119 056401 (2017). [2] Pascal Delange, Silke Biermann, Takashi Miyake, Leonid Pourovskii, Phys. Rev. B 96, 155132 (2017). [3] S. Panda, L. Pourovskii, S. Biermann, in preparation.

MA 7.2 Mon 10:45 TC 010

Continuous transition from antiferro- to ferromagnetic state via moment canting in $Ni_{2-x}Co_xMnAl$ — •Michael Leitner[1], Pascal Neibecker[1], Matthias Opel[2], Xiao Xu[3], Ryosuke Kainuma[3], and Winfried Petry[1] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, Lichtenbergstr. 1, 85748 Garching — [2]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching — [3]Department of Materials Science, Tohoku University, Sendai 980-8579, Japan

The magnetic structure of materials is often discussed only in terms of the classical concepts of ferromagnetism and antiferromagnetism, however, interesting phenomena can be expected when a system is driven to the boundary between these regimes by adjusting external parameters. B2-ordered $Ni_{2-x}Co_xMnAl$ is a case in point: Ni_2MnAl, a potential ferromagnetic shape-memory material, displays antiferromagnetism [1], while NiCoMnAl, predicted to be a halfmetal, is ferromagnetic [2].

We have studied this system for $0 \leq x \leq 0.8$. Temperature-dependent neutron powder diffraction proves an antiferromagnetic ordering for $x < 0.4$, while the macroscopic magnetization shows an increasing longitudinal component for all $x > 0$. We argue that this constitutes a continuous, spatially homogeneous transition from antiferro- to ferromagnetism via canted spins, which is reproduced by a simple Heisenberg model.

[1] M. Acet et al., *J. Appl. Phys.* **92**, 3867 (2002)

[2] P. Neibecker et al., *Phys. Rev. B* **96**, 165131 (2017)

MA 7.3 Mon 11:00 TC 010

Modeling the high-temperature paramagnetic state of magnetic materials from first-principles - coupling of lattice vibrations and disordered magnetism — •Björn Alling[1,2] and Irina Stockem[1,2] — [1]Linköping University, Sweden — [2]Max-Planck-Institut für Eisenforschung, Düsseldorf, Germany

The paramagnetic state of magnetic materials lack global magnetization and long range order between moments. However, in most cases there still exist important local magnetic moments. Also, lattice vibrations are important for properties and stability of materials at high temperature. Simultaneous presence of disorder of magnetic and vibrational nature poses a severe challenge for first-principles theory.

I present our recently developed method combining atomistic spin dynamics with ab-initio molecular dynamics (ASD-AIMD) treating the magnetic and vibrational degrees of freedom on an equal, first-principles based footing. It allows us to explicitly study the coupled dynamics of magnetism and lattice in the paramagnetic state.

We use it to study paramagnetic CrN. Phonon life times are obtained from the AIMD part of the simulations. At 300 K, we see dramatically lower phonon lifetimes as compared to an adiabatic, fast-magnetism, approximation. Further, the phonon lifetime does not decrease in the normal manner with increasing temperature which could explain anomalys thermal conductivity observed experimentally for many materials in the paramagnetic state. These results underline the importance of allowing for a dynamical coupling between magnetism and lattice vibrations in theoretical studies of the paramagnetic state.

MA 7.4 Mon 11:15 TC 010

Lattice relaxations in paramagnetic materials from first principles — •Davide Gambino[1] and Björn Alling[1,2] — [1]Department of Physics, Chemistry, and Biology (IFM) Linköping University, SE-58183 Linköping, Sweden — [2]Max-Planck-Institut für Eisenforschung GmbH, D-402 37 Düsseldorf, Germany

The first-principles calculation of many material properties starts with the relaxation of the atomic positions of the system under investigation. This procedure is routine for nonmagnetic materials, as well as for magnetically ordered compounds. However, when it comes to magnetically disordered systems, it is not clear what geometry one should take into account. Here we propose a method for the structural relaxation of magnetic materials in the paramagnetic regime within the disordered local moment (DLM) picture in the framework of density functional theory (DFT). The method can be easily implemented using any ab initio code.

We consider as a test case Fe vacancy in bcc Fe in the paramagnetic regime: as a result, the nearest neighbors to the vacancy relax inwards of about 0.16 Angstrom (-5% of the ideal bcc nearest neighbor distance), which is twice as large as the relaxation in the ferromagnetic case, and the vacancy formation energy calculated on these positions results to be 1.60 eV, which corresponds to a reduction of about 0.1 eV compared to the formation energy calculated on ferromagnetic-relaxed positions. Our results are in good agreement with recent DFT+DMFT calculations and with experimental values. Other systems under investigations are interstitial defects in bcc Fe and FeCr random alloys.

15 min. break

Topical Talk MA 7.5 Mon 11:45 TC 010

We need perfect defects - challenging the Brown's paradox in permanent magnetism — •Oliver Gutfleisch — TU Darmstadt, Materialwissenschaft

It is common understanding that among the intermetallic phases used for high performance permanent magnets, practically none can fully realize its potential based on the intrinsic magnetic properties. Even if the grain size of the fully-dense magnet is close to the single domain size, the coercivity Hc is usually one order of magnitude smaller than the anisotropy field Ha - this situation is known as Brown's paradox. The presence of crystallographic defects of various kinds, of secondary phases, of surface imperfections as well as magnetic inhomogeneities leads to local magnetic softening. On the other hand, a perfect single crystal shows 'no' coercivity whatsoever. Looking at nucleation-type NdFeB (1,2) and pinning type SmCo (3) magnets we will revisit the Brown's paradox and discuss possible ways of overcoming it.

1 Helbig et al., Experimental and Computational Analysis of Magnetization Reversal in (Nd,Dy)-Fe-B Core Shell Sintered Magnets, Acta Materialia 127 (2017) 498.

2 Loewe et al., Grain boundary diffusion of different rare earth elements in Nd-Fe-B sintered magnets by experiment and FEM simulation, Acta Materialia 124 (2017) 421.

3 Duerrschnabel et al., Atomic structure and domain wall pinning in samarium -cobalt based permanent magnets, Nature Communications 8:54 (2017).

Topical Talk MA 7.6 Mon 12:15 TC 010

Interplay of moment-volume and electron-phonon coupling in the itinerant electron metamagnet LaFe$_{13-x}$Si$_x$H$_y$ — •Markus Ernst Gruner — Faculty of Physics and Center for Nanointegration, CENIDE, University of Duisburg-Essen, Germany

LaFe$_{13-x}$Si$_x$H$_y$ compounds belong to the most promising systems for room temperature magnetic refrigeration. Here, large adiabatic temperature and isothermal entropy changes in an external magnetic field are obtained at a first-order metamagnetic transition. It is accompanied by a large volume change without change in lattice symmetry, attributed to the competition of different magnetic states of Fe associated with varying atomic volumes. Recently, we detected by first-principles lattice dynamics and nuclear resonant inelastic X-ray scattering characteristic changes in the vibrational density of states at the magnetic transition in LaFe$_{13-x}$Si$_x$, which involves the disappearance of a high-energy peak in connection with an overall softening of phonons in the paramagnetic phase. This contributes to the good magneto- and barocaloric properties of the material, in terms of a cooperative contribution of magnetic, electronic and vibrational degrees of freedom to the entropy change. The softening originates from adiabatic electron-phonon coupling caused by specific changes in the electronic density of states at the Fermi level, which are sensitive to the magnitude of the Fe moment, rather than to magnetic order. Finally, we demonstrate that the same mechanisms are effective in the hydrogenated compound at ambient conditions.
Funding by the DFG within SPP 1599 is gratefully acknowledged.

MA 7.7 Mon 12:45 TC 010

Spin-lattice effects in LaFe$_{11.6}$Si$_{1.4}$ revealed by powder diffraction — •Tom Faske[1], Wolfgang Donner[1], and Markus Hölzel[2] — [1]TU Darmstadt, Materials Science, Structure Research, Darmstadt, Germany — [2]Heinz Maier-Leibnitz Zentrum, Garching, Germany

LaFe$_{13-x}$Si$_x$ ($x = 1.0 - 1.6$) is a promising material class for application in magnetic cooling and has been extensively studied in recent years. For $x \leq 1.6$ it exhibits a first order magneto-structural phase transition around 200 K which becomes second order for $x > 1.6$. The first-order transition is accompanied by a large isothermal entropy change $|\Delta S_{iso}|$ in conjunction with a high adiabatic temperature change $|\Delta T_{ad}|$, which are both important figures of merit for a potential magnetocaloric application.

Here we report on the detailed study of the first-order phase transition of LaFe$_{13-x}$Si$_x$ by means of temperature and magnetic field dependent x-ray and neutron powder diffraction. External magnetic fields increase the Curie temperature by ≈ 4 K/T, so that the phase transition could be induced thermally and by applying magnetic fields of up to 5 T during the diffraction experiments. In a narrow magnetic field and temperature range, both phases were present in the diffraction patterns. Subtle structural differences in the two-phase region between the magnetic field and temperature induced phase transitions revealed a change in the entropy transfer of the two systems.

MA 7.8 Mon 13:00 TC 010

Symmetry breaking induce robust monoclinic-distortion and unconventional charge ordering at room temperature in single crystal of Na2.7Ru4O9 — •Arvind Yogi[1,2], C. I. Sathish[1,2], Hasung Sim[1,2], Y. Noda[3], and Je-Geun Park[1,2] — [1]Center for Correlated Electron Systems, Institute for Basic Science (IBS), Seoul 08826, Korea — [2]Department of Physics and Astronomy, Seoul National University, Seoul 08826, Korea — [3]Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Sendai 980-8577, Japan

We discovered by combining the results of SC-XRD, electrical resistivity, specific heat, and susceptibility that Na2.7Ru4O9 with the monoclinic new tunnel type lattice (space group P 21/m) evolves an unprecedentedly charge ordering (CO) at room temperature while retaining of metallicity. The temperature dependent SC-XRD results shows super-lattice peaks q1 (0, 1/2, 0) and q2 (0, 1/3, 1/3), that causes the translation symmetry breaking of the lattice which induces robust monoclinic-distortion at room temperature, is the evidence for the formation of an unconventional charge ordering (CO). Na2.7Ru4O9 show a first-order phase transition in the electrical resistivity with two consecutive transitions at Tc (1) = 365 K and Tc (2) = 345 K for Na2.7Ru4O9 which supports well by magnetization and heat-capacity results. The electron-phonon mediated scattering mechanism is involved in the resistivity. We argue that the origin of unprecedented CO is due to the localized 4d electrons.

MA 8: Focus Session: Magnetic structurally and compositionally modulated nanowires and nanotubes

There is an increasing scientific activity on magnetic nanowires and nanotubes with tunable circular section (as opposed to nanostripes). Length, diameter, shell thickness and materials can be selected from a wide range of magnetic alloys and elements. Axially and radially modulated structured can be synthesized. These families of cylindrical wires and tubes are currently proposed in a number of applications ranging from specific media for magnetic memory applications (*race-track*), microwave applications (*stealth* absorbing materials), magnetic sensing elements and logic devices at the nanoscale (nano-technology), or for applications based on their magneto-thermo-electrical properties (*energy conversion and harvesting*). Other relevant applications include their organic functionalization for a number of biomedical applications. Most of those applications derive from their unique magnetic characteristics namely the magnetic configuration (e.g., magnetic domains), demagnetization process (e.g., nucleation and depinning of transverse or vortex domain walls; coherent/non-coherent rotational processes), and frequency dependent behaviour (e.g., microwave absorption phenomena). In short, the motivation of this Mini-colloquium is to bring together specialists and scientists interested in novel applications of anisotropic nanostructures to discuss and exchange ideas on both fundamental and applied issues of these nanowires and nanotubes.

Organized by: Manuel Vazquez (ICMM-CSIC, Madrid), Michael Farle (U. Duisburg-Essen), Kornelius Nielsch (IFW Dresden)

Time: Monday 15:00–18:30 Location: H 1012

Invited Talk MA 8.1 Mon 15:00 H 1012

Multiple nanostructures based on anodized aluminium oxide templates — •Yong Lei — Institut für Physik & IMN MacroNano (ZIK), Technische Universität Ilmenau, 98693, Ilmenau, Germany

New physical phenomena and superior properties in solids usually involve couplings of adjacent materials and architectures in nano-scale. Binary nanostructure arrays, capable of introducing intimate interactions between different sub-component arrays, could raise a new horizon of nanotechnology. Here we proposed a concept to achieve diverse binary nanostructure arrays with high degrees of controllability for each of the sub-components, including material, dimension, and morphology. This binary nano-structuring concept originates from a distinctive binary-pore anodic aluminum oxide template that possesses two dissimilar sets of pores in one matrix. Moreover, the binary-pore template is evolvable to multi-pore (ternary and quadruple) templates with higher pore densities and more morphologic options. Binary nanostructure arrays with different material and morphology combinations were explored, and shall lead towards applications such as in catalysis, energy conversion and magnetic devices. [1] Wen L., Xu R., Mi Y., Lei Y., Nature Nanotechnology, 12, 244, 2017.

MA 8.2 Mon 15:30 H 1012

3D cobalt nanotubes grown by focused electron beam induced deposition — Javier Pablo-Navarro[1], •César Magén[1,2], Amalio Fernandez-Pacheco[3], Luis Alfredo Rodriguez[4], and José María De Teresa[1,2] — [1]Laboratorio de Microscopias Avanzadas (LMA), Instituto de Nanociencia de Aragon (INA), Universidad de Zaragoza, 50018 Zaragoza, Spain — [2]Instituto de Ciencia de Materiales de Aragon (ICMA), Universidad de Zaragoza-CSIC, 50009 Zaragoza, Spain — [3]Cavendish Laboratory, University of Cambridge, JJ Thomson Avenue, Cambridge CB3 0HE, UK — [4]Departamento de Física, Universidad del Valle, A. A. 25 360, Cali, Colombia

Magnetic nanotubes are potential candidates for fast and low-power domain wall conduit in future 3D spintronic devices. We report for the first time the successful growth of 3D cobalt nanotubes by focused electron induced deposition (FEBID) on 3D Pt-FEBID nanowire templates of 100 nm in diameter. Cross sectional Transmission Electron Microscopy characterization has confirmed that nanotubes with a wall thickness down to 11 nm can be achieved. These cobalt nanotubes are nanocrystalline and present a metallic content of 70 at. Co%. Magnetic characterization by electron holography and MOKE magnetometry experiments on individual nanotubes demonstrate that these nanostructures are ferromagnetic, with an estimated remanent magnetic induction of 0.9 T and coercivity around 160 Oe. This work evidences that FEBID is a suitable technique to grow complex functional heterostructures in 3D with potential for application in high density magnetic memory and logic devices.

Invited Talk MA 8.3 Mon 15:45 H 1012

Towards a three dimensional curvilinear magnonic transducer — •Jorge A Otalora[1], Jürgen Lindner[2], Helmut Schultheiss[2], Kilian Lenz[2], Andy Thomas[1], Kornelius Nielsch[1,3], and Attila Kákay[2] — [1]Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden), Institute for Metallic Materials, 01069 Dresden, Germany — [2]HZDR, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [3]Technische Universität Dresden, Institute of Materials Science, 01062 Dresden, Germany

Curving a two dimensional magnetic membrane gives rise to asymmetries in the spin-waves (SWs) properties. Magnetic nanotubes provides an example, for which the mean curvature of the tubular shape creates asymmetries in frequency and lifetime in a similar fashion like the Dzyaloshinskii-Moriya interaction in a ferromagnetic/heavy metal interface. Here, an inductive transducer composed of two coplanar wave guides and a magnetic nanotube is proposed, predicting a straightforward access to the curvature-induced asymmetric properties of SWs via detecting the reflection/transmission parameters of the device. With the presented results, it is expected to give a step further towards the implementation of curved membranes as three dimensional layouts for magnonic applications.

Invited Talk MA 8.4 Mon 16:15 H 1012

Controlled domain wall propagation in cylindrical nanowires — •Cristina Bran — Institute of Materials Science of Madrid, CSIC, 281049 Madrid, Spain

Cylindrical magnetic nanowires represent an alternative for nanotechnological applications such as 3D magnetic recording [1], actuators or sensors and logical devices where the control over the position and motion of domain wall (DW) is crucial. The nanowires present important advantages such as: the possibility to tailor the DW shape or the stability and high velocity of DW during its motion due to suppression of Walker breakdown [2]. Here we show a way of controlling DW propagation in these one-dimensional nanostructures by specific designs in geometry (i.e., modulations of diameter), or in magnetic anisotropy (i.e., modulations in the composition) [3]. In this way, the modulation will act as pinning center for nucleation, pinning and depinning of DWs. These local variations changes the typical single-domain state present in soft NWs, as well as the mono domain wall-type switching of the magnetization based on the DW nucleation and propagation. A detailed description of the magnetic configuration of individual cylindrical Co-based NWs is presented by combining XMCD-PEEM which allows resolving the surface and the internal magnetic structure of NWs, magneto-optical Kerr effect and micromagnetic simulations. [1]. S. Parkin et al., Nature Nanotechnology 10, 195 (2015). [2]. M. Yan et. al. Phys. Rev. Lett. 104 (2010) 057201 [3]. C. Bran et al., J. Mater. Chem. C 4, 978 (2016)

15 minutes break

Invited Talk MA 8.5 Mon 17:00 H 1012

Magnetic hardening of nanowires by sandwiching with antiferromagets — •Ulf Wiedwald — Faculty of Physics and Center for Nanointegration Duisburg-Essen, University of Duisburg-Essen, Germany — National University of Science and Technology MISIS, Moscow, 119049, Russian Federation

The growth of magnetic nanowires (NWs) in anodic aluminum oxide (AAO) is a nowadays well-established technique [1]. Such NWs have been suggested as rare earth-free permanent magnets or magnetoelectric logic devices [2]. Exploiting the shape anisotropy of 3d-metal NWs at aspect ratios of several hundred in principle yields in a huge magnetic energy product. However, due to vortex formation at the tips and dipolar coupling of neighboring wires it is significantly reduced.

Interfacing the tips with antiferromagnet layers is suitable to overcome such limitations as recently shown by oxidation [2]. We explore the magnetic hardening of FeCo NWs at 300 K by coating their tips with antiferromagnetic FeMn. For this purpose, free-standing tips of micron-long NWs with a diameter of 40 nm are isolated from the AAO membranes and covered with few nm FeMn. In the resulting sandwich structure, the energy product doubles at 300 K due to suppression of vortices [3]. Financial support of the Ministry of Education and Science of the Russian Federation, Increase Competitiveness Program of NUST MISiS K3-2017-022 is gratefully acknowledged.

[1] K. Nielsch et al., Appl. Phys. Lett. 79, 1360 (2001). [2] S. Liébana-Viñas et al., Nanotechnol. 26, 415704 (2015). [3] FZ. Wang et al. Nanotechnol. 28, 29 (2017).

MA 8.6 Mon 17:30 H 1012

Magnetization reversal and local switching fields of ferromagnetic microtubes with radial magnetization — •Norbert Puwenberg[1], Christopher Friedrich Reiche[1], Mishal Khan[1], Robert Streubel[2], Michael Melzer[1], Oliver Schmidt[1,3], Bernd Büchner[1,4], and Thomas Mühl[1] — [1]IFW Dresden, Dresden, Germany — [2]Lawrence Berkeley National Laboratory, Berkeley, USA — [3]TU Chemnitz, Chemnitz, Germany — [4]Technische Universität Dresden, Dresden, Germany

A simple type of three-dimensional magnetic nanostructures can be formed by rolling-up magnetic thin films. We investigated the field-dependent stray-field distribution of rolled-up Co/Pd nanomembranes [1] by multi-frequency magnetic force microscopy (MFM) under vacuum conditions. Stray field and topography were mapped simultaneously by employing mechanical and electrostatic AC excitation of the fundamental and the second flexural cantilever oscillation mode [2]. We will present MFM images showing demagnetized multi-domain states as well as homogeneous remanent states after saturation. The detailed evaluation of field-dependent MFM series shows that the spatially resolved switching fields depend on the angle between the direction of the applied magnetic field perpendicular to the tube axis and the local surface normal of the tube surface. Our data corresponds to an angle range of 0° to 65°, which points to a Kondorsky-type behavior of the magnetization reversal in our rolled up Co/Pd nanomembranes.

[1] R. Streubel et al., Nature Communications 6, 7612 (2015)
[2] J. Schwenk et al., Appl. Phys. Lett. 107, 132407 (2015)

Invited Talk MA 8.7 Mon 17:45 H 1012

Hybrid Magnetoelectric Nanowires for Nanorobotic Applications — •Salvador Pané — Multi-Scale Robotics Lab, ETH Zürich, Switzerland

Over the past two decades researchers have been working to create synthetic small-scale machines ranging from molecular entities or miniaturized structures, to more complex assemblies of micro- and nanomaterials. These machines are able to navigate in complex environments by harvesting fuel from the surrounding media or from external powersources. One of the most sought-after applications for these miniaturized machines is to perform minimally invasive interventions, in which these devices will ultimately reduce risk, cost, and discomfort compared to conventional interventions. While recent research has demonstrated the potential of these devices, a number of obstacles remain in moving small-scale robots into the operating theatre. One of the major challenges is the development of miniaturized mobile platforms capable of integrating multiple functionalities. In this talk, we will present magnetoelectric-composite nanowire-based machines that, under the same source of energy, are able to perform two different functionalities depending on how magnetic fields are applied. The magnetostrictive component enables this machine to propel, while the magnetoelectric composite can be used to wirelessly generate a piezoelectric field. We will focus on the potential biomedical applications of these magnetoelectric small-scale robots. As an example, we will show core-shell magnetoelectric nanowires, which are able to release in vitro anti-cancer drugs on-demand using the magnetoelectric approach.

MA 8.8 Mon 18:15 H 1012

Magnetism and Transport in Hybrid Magnetic Nanowires — •Roman Hartmann, Sergej Andreev, and Torsten Pietsch — Fachbereich Physik, Universität Konstanz, 78464 Konstanz, Germany

Spin-based electronics present an alternative to conventional electronic devices. For example, spin-transfer nano-devices offer higher switching speeds and greatly reduced dissipative loss but often require large operation currents and are difficult to manufacture.

Herein we present a simple but versatile concept to fabricate complex magnetic nanowire devices in a single processing step via electrodeposition into a self-organized anodic aluminum (AAO) template. We demonstrate the fabrication of heteronanowires composed of magnetic multilayers of different ferro- and paramagnetic metals and alloys (e.g. Ni, Cu, NiCu) with diameters around 30 nm, which greatly reduces the drive current. Device integration is done using lithographic methods. The static and dynamic magnetic properties are analysed via SQUID magnetometry, FMR and electron transport spectroscopy. Due to their intrinsic multilayer geometry and large number of parallel wires, these structures can be employed in magnetic nano-oscillators for microwave generation and detection with optimized output power and sensitivity respectively.

MA 9: Magnetic domain walls

Time: Monday 15:00–18:15 Location: EB 202

MA 9.1 Mon 15:00 EB 202

Emergence of antiferromagnetic domains out of domain walls — •Ehsan Hassanpour Yesaghi[1], Mads C. Weber[1], Amadé Bortis[1], Thomas Lottermoser[1], Yusuke Tokunaga[2], Yasujiro Taguchi[3], Yoshinori Tokura[3], and Manfred Fiebig[1] — [1]ETH Zurich, Switzerland — [2]Univ. of Tokyo, Japan — [3]RIKEN CEMS, Japan

Antiferromagnetic (AFM) materials are gaining increasing attention for their potential in technological applications such as spintronics. Strong coupling and faster dynamics as well as robustness against magnetic stray fields are their attractive properties. This robustness, however, makes it chronically difficult to influence AFM states. We propose to manipulate the AFM ordering through the controlled emergence of bulk domains at the phase transition. To demonstrate this, we investigate the weakly-ferromagnetic (wFM) to AFM phase transition in (Dy,Tb)FeO_3 which is driven by strongly coupled ordering of magnetic rare-earth and iron ions. The wFM ordering, which can be influenced by an external magnetic field, can persist as a metastable state in the AFM phase. By employing spatially-resolved magneto-optical methods, we demonstrate that AFM domains can emerge out of antiphase domain boundaries of the metastable wFM phase. Furthermore, we design domain-wall configurations that allow the nucleation of two oppositely oriented AFM domains separated by a wFM domain wall. We show with a simple model that symmetry of the domain wall in one phase is the key to seed the nucleation of the desired domain orientation of the other phase.

MA 9.2 Mon 15:15 EB 202

Experimental and numerical study of 360 degree domain wall annihilation — •Gurucharan V. Karnad[1], Eduardo Martinez[2], Michele Voto[2], Tomek Schulz[1], Berthold Ocker[3], Dafiné Ravelosona[4], and Mathias Kläui[1] — [1]Institut für Physik , Johannes Gutenberg-Universität Mainz, Mainz, Germany — [2]Departamento Fisica Applicada, Universidad de Salamanca, Salamanca, Spain — [3]Singulus Technology AG, Kahl am Main, Germany — [4]Centre for Nanoscience and Nanotechnology, University Paris-Saclay, Orsay, France

In the presence of interfacial Dzyaloshinkii-Moriya interaction (DMI) the domain walls (DWs) adopt a homochiral configuration. When two neighboring walls are in close proximity, they form winding pairs as they possess the same winding number. This leads to additional dipolar interaction which is directly related to the magnitude of the DMI. This is directly reflected in the terminal field which is required to annihilate the domain walls. We present an analytical model where we show that the contribution to dipolar repulsion by DMI can be modified under the application of external magnetic fields. This is further verified by micromagnetic simulations which propose an experimental set-up to observe this. This is experimentally realized and demonstrated in a system of Ta/Co20F60B20/MgO and Pt/Co/AlOx.

MA 9.3 Mon 15:30 EB 202

Effective description of domain walls as extended structures — •Davi Rohe Rodrigues[1,2,3], Karin Everschor-Sitte[2,4], Jairo Sinova[2], and Artem Abanov[1] — [1]Department of Physics & Astronomy, Texas A&M University, College Station, Texas 77843-4242, USA — [2]Institute of Physics, Johannes Gutenberg Universitat, 55128 Mainz, Germany — [3]Graduate School Materials Science in Mainz, Staudingerweg 9, 55128 Mainz, Germany — [4]Institute of Physics ASCR, v.v.i, Cukrovarnicka 10, 162 00 Prag 6, Czech Republic

Domain walls are often treated as one-dimensional objects whose dynamics is described by two soft modes, its position and azimuthal angle. In thin films, however, domain walls exhibit a richer structure including vortices and curvatures. We propose an effective description for domain walls as extended objects with local degrees of freedom. Our description includes tilted[1,2] domain walls, vortices[3], and more complex configurations. We analyze the transport of spin waves along the domain walls and the formation of cusps. Furthermore, considering Skyrmions as closed domain walls, we study the effects of deformations along their borders. Going beyond the often used circular approximation for skyrmions[4] we find for example that deformations in the skyrmion shape travel along its border. [1] Boulle, et al, PRL 111 (2013); [2] Muratov, et al, PRB 96, 134417 (2017); [3] Tretiakov, et al, PRL 100, 127204 (2008); [4] Rodrigues, et al, (manuscript in preparation).

MA 9.4 Mon 15:45 EB 202

Dynamical depinning of chiral domain walls — •Simone Moretti[1,2], Michele Voto[2], and Eduardo Martinez[2] — [1]Department of Physics, University of Konstanz, 78457, Konstanz, Germany — [2]Department of Applied Physics, University of Salamanca, 37001, Salamanca, Spain

The domain wall depinning field represents the minimum magnetic field needed to move a domain wall, typically pinned by defects or patterned constrictions. From a technological point of view, it represents an important parameter since a small depinning field implies less energy required to move a domain wall and, therefore, an energetically cheaper (domain wall based) device. Conventionally, such field is considered independent on the Gilbert damping since it is assumed to be the field at which the Zeeman energy equals the pinning energy barrier (both damping independent). Consequently, a large or small depinning field is usually interpreted only in terms of the disorder strength of a certain sample. Here we analyse numerically the domain wall depinning field as a function of the Gilbert damping in a system with perpendicular magnetic anisotropy and Dzyaloshinskii-Moriya interaction. Contrary to expectations, we find that the depinning field depends also on the Gilbert damping and that it strongly decreases for small damping parameters. We explain this dependence with a simple one-dimensional model and we show that the reduction of the depinning field is related to the finite size of the pinning barriers and to the domain wall precessional dynamics, connected to the Dzyaloshinskii-Moriya interaction and the shape anisotropy.

MA 9.5 Mon 16:00 EB 202

A numerical study on ferrimagnetic domain wall motion in

temperature gradients — •Andreas Donges[1], Unai Atxitia[2], Thomas Schönenberger[3], Severin Selzer[1], and Ulrich Nowak[1] — [1]Fachbereich Physik, Universität Konstanz, DE-78457 Konstanz, Germany — [2]Fachbereich Physik, Freie Universität Berlin, DE-14195 Berlin, Germany — [3]École Polytechnique Fédérale de Lausanne, CH-1015 Lausanne, Switzerland

We investigate the domain wall (DW) dynamics of a typical rare earth-transition metal ferrimagnet in a constant temperature gradient using atomistic Langevin dynamics simulations based on the stochastic Landau-Lifshitz-Gilbert equation. Our results are compared to the ferro- and antiferromagnetic DW motion which have been studied more thoroughly so far [1,2]. Surprisingly, below the angular momentum compensation temperature T_A, we find a regime in which the DW is moving towards the colder region, i.e. against Schlickeiser's entropic torque [1] which suggests a drift into the hotter region. Recently, Moretti et al. [3] showed that such a reversed DW motion might be connected to spin wave reflections. Furthermore, our simulations suggest the existence of a torque compensation point $T_\mathrm{T} > T_\mathrm{A}$, at which the DW precession changes sign. This also implies that a DW propagating along such a temperature gradient can undergo two Walker breakdowns: one above and one below T_T.

[1] F. Schlickeiser, et al., *Phys.Rev.Lett.* **113**, 097201 (2014)
[2] S. Selzer, et al., *Phys.Rev.Lett.* **117**, 107201 (2016)
[3] S. Moretti, et al., *Phys.Rev.B* **95**, 064419 (2017)

15 minutes break

MA 9.6 Mon 16:30 EB 202

Properties of ferrotoroidic domains in artificial nanomagnetic crystals — •Jannis Lehmann[1], Claire Donnelly[1,2], Naëmi Leo[2], Peter Derlet[2], Laura Heyderman[1,2], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zurich, Switzerland — [2]Paul Scherrer Institute, Villigen PSI, Switzerland

Periodic nanomagnetic arrays can be seen as model spin systems which allow a direct study of spontaneous order, magnetic frustration or other phenomena that emerge at the mesoscale. The possibility to design an artificial magnetic crystal and engineer the magnetic-dipole-based lattice potentials on demand opens the door to novel ferroic systems. Here we apply the concept of artificial crystals to examine ferrotoroidicity, an order that is based on magnetic moments forming a vortex at the level of a unit cell. This arrangement yields a toroidal moment as the associated order parameter. We introduce a two-dimensional nanomagnetic array that provides as-grown toroidal domains. By studying different systems with tailored magnetic-dipole strength via magnetic force microscopy we show how the dipole coupling determines the as-grown domain size and gives rise to an anisotropy in our domain walls. The magnetic configurations of a domain wall are of particular interest as they can be tuned to exhibit a ferro- or an antiferromagnetic-like ordering along the propagation direction of the wall. Our results demonstrate the control of domain size and domain-wall geometry in artificial magneto-toroidal crystals. This work provides an experimental approach for modelling and tailoring ferroic systems and for scrutinizing fundamental properties of ferrotoroidicity.

MA 9.7 Mon 16:45 EB 202

Monte-Carlo approach to ferrotoroidic domains in artificial crystals — •Amadé Bortis[1], Peter Derlet[2], Jannis Lehmann[1], Thomas Lottermoser[1], and Manfred Fiebig[1] — [1]Department of Materials, ETH Zürich, Switzerland — [2]Paul Scherrer Institute, Villigen PSI, Switzerland

Amongst the primary ferroic orders, ferrotoroidicity is least investigated and understood. Ferrotoroidic systems are defined by a chiral arrangement of magnetic moments which can be associated to a toroidic order parameter. Due to the scarcity of materials which show ferrotoroidicity on a microscopic scale, artificial crystals can be used to reproduce ferrotoroidic order on the mesoscale. These artificial nanomagnetic arrays consist of magnetic islands which are coupled through magnetic-dipole interactions. This implies that the interactions are well defined and tunable, allowing for geometric arrangements which show ferrotoroidic order. The magnetic islands can be modeled as classical Ising spins, which makes kinetic Monte-Carlo simulations (KMC) an efficient tool to investigate the formation of toroidic domains. Domain formation in these systems generally depends on the growth rate and the geometry which determines the strength of the dipolar interactions. We use KMC to understand the correlation of toroidic domains and domain walls as a function of the geometry. We find that the relative coupling strengths in between the islands determines the specific arrangement of the domain walls as well as the the average domain size. Our work provides new insights towards the understanding of ferrotoroidic domains and how they may be tuned.

MA 9.8 Mon 17:00 EB 202

Scanning Reflection X-ray Microscope (SRXM) - a new tool for magnetic domain imaging — •Andreas Schümmer[1], Hans-Christoph Mertins[1], Roman Adam[2], Claus Schneider[2], Larissa Juschkin[3], and Ulf Berges[4] — [1]University of Applied Sciences Münster, 48565 Steinfurt, Germany — [2]Forschungszentrum Jülich,52428 Jülich, Germany — [3]Rhein Westfälische Technische Hochschule Aachen, 52062 Aachen, Germany — [4]TU Dortmund, Zentrum für Synchrotronstrahlung, 44227 Dortmund, Germany

We present the first results of the newly developed scanning reflection x-ray microscope (SRXM) operating in the extreme ultraviolet (EUV) spectral range. Focus lies on the mechanical setup, efficient fabrication process of zone plate optics and first results in structural and element-selective imaging. The SRXM is dedicated for imaging of magnetic domains in buried layers exploiting magneto-optical reflection spectroscopy in T-MOKE, or for XMCD [1] under incidence angles from 20° to 60°. The advantage of working in the EUV region is the access to the 3p absorption edges of 3d transition metals. In addition, the intensity of reflected light is about two orders of magnitude higher than at the 2p edges. [1] M. Tesch, M. Gilbert, H-Ch. Mertins, D. Bürgler et al., Appl. Opt.52, 4294 (2013)

MA 9.9 Mon 17:15 EB 202

Magnetoelectric Force Microscopy on Antiferromagnetic 180° Domains in Cr_2O_3 — •Marcela Giraldo[1], Peggy Schoenherr[1], Martin Lilienblum[1], Morgan Trassin[1], Dennis Meier[2], and Manfred Fiebig[1] — [1]ETH Zurich, Switzerland. — [2]NTNU, Norway.

Scanning probe microscopy (SPM) techniques constitute the most widely-used characterization tool on the nanoscale. The diversity of operational modes makes them versatile tools with impact in a broad range of fields. SPM techniques proved particularly useful in the investigation of ferroic materials. Even though local ferroic properties have been studied by these techniques, the approach to antiferromagnetic order is almost non-existent. This is regrettable because antiferromagnets are getting increasing attention in recent years. Since antiferromagnets do not exhibit a net magnetization, it is not trivial to access or control them. Efforts aimed at understanding their properties at the domain level are key to their systematic manipulation. In my talk, I will discuss a benchmark experiment and the methodical aspects of a previously proposed SPM technique, termed magnetoelectric force microscopy, as a probe for the elusive type of 180° antiferromagnetic domains in a well known textbook material, Cr_2O_3. Direct comparison by second harmonic generation allows detecting its inherent advantages. I will finally draw your attention on further improvements of the technique which would increase its feasibility to cover most of the known bulk compounds and may even be sufficient to resolve antiferromagnetic domains in type-II multiferroics or magnetoelectric heterostructures.

MA 9.10 Mon 17:30 EB 202

Spin transfer torques in interacting quantum wires — •Hamidreza Kazemi[1], Nicholas Sedlmayr[2], Axel Pelster[1], Imke Schneider[1], and Sebastian Eggert[1] — [1]TU Kaiserslautern and Research Center OPTIMAS, Kaiserslautern, Deutschland — [2]TU Rzeszów, Rzeszów, Poland

The use of spin polarized currents for the manipulation of magnetic domain walls (DW) in ferromagnetic nanowires has been the subject of intensive research in recent years [1]. This is due to the promising application of such mechanisms e.g. in DW based magnetic devices.
Our main goal is the inquiry into the full quantum effects of electron-electron correlation on the non-adiabatic spin transport in quasi one-dimensional nano-structures with magnetic DWs. It is known that the electrons confined to a one-dimensional wire behave fundamentally different from standard Fermi-liquid quasiparticle picture so that a characteristic change in the spin transfer torque is expected. In this respect, bosonization technique is used to go beyond mean-field theory in 1D nanowires with sharp DWs [2] in order to calculate the corresponding spin transfer torques.

[1] A. Brataas, A. D. Kent, and H. Ohno. Nat.Mater. **11**, 372.381 (2012).

[2] N., S. Sedlmayr, S. Eggert, and J. Sirker. Phys.Rev.B **84**, 024424 (2011).:

MA 9.11 Mon 17:45 EB 202

Wire edge dependent magnetic domain wall creep — •Liza Herrera Diez[1], Vincent Jeudy[2], Gianfranco Durin[3], Arianna Casiraghi[3], Juergen Langer[4], Berthold Ocker[4], and Dafiné Ravelosona[1] — [1]Centre de Nanosciences et de Nanotechnologies, CNRS, Univ. Paris-Sud, Université Paris-Saclay, C2N Orsay, 91405 Orsay cedex, France — [2]Laboratoire de Physique des Solides, CNRS, Univ. Paris-Sud, Université Paris-Saclay, 91405 Orsay Cedex, France — [3]Istituto Nazionale di Ricerca Metrologica, Strada delle Cacce 91, 10135 Torino, Italy — [4]Singulus Technology AG, Hanauer Landstrasse 103, 63796 Kahl am Main, Germany

While edge pinning is known to play an important role in sub-μm wires, we demonstrate that strong deviations from the universal creep law can occur in 1 to 200μm wide wires. Edge pinning increasingly dominates the creep dynamics as the wire width decreases and it is also found to depend on aging and different fabrication processes. Magnetic imaging reveals that edge pinning deviations correlate with a marked bending of domain walls at low drive. This behaviour is described by a mixed-creep mechanism combining the creep law exponent $\mu = 1/4$ describing bulk pinning and an additional component accounting for edge pinning with an exponent of 0.38.

MA 9.12 Mon 18:00 EB 202

Exchange coupling torque in antiferromagnetically coupled Co/Gd bi-layer system — •Robin Bläsing[1,2], See-Hun Yang[3], Tianping Ma[1,2], Chirag Garg[1,2,3], and Stuart S. P. Parkin[1,2,3] — [1]Max Planck Institute for Microstructure Physics, Halle , Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, Halle, Germany — [3]IBM Research Almaden, San Jose, USA

In antiferromagnetic and ferrimagnetic thin films the efficiency of current-induced domain wall motion (CIDWM) by spin Hall currents from a heavy metal underlayer like Pt can be dramatically raised compared to ferromagnetic systems. As soon as the total angular momentums of the magnetic sublattices are equal, the torque due to the Dzyaloshinskii Moriya interaction (DMI) tends to zero and the more efficient exchange coupling torque becomes the dominant driving force. We carried out CIDWM experiments in antiferromagnetically coupled Co/Gd systems at base temperatures between 125 K and 250 K. The change of the magnetization of Gd due to the change of temperature within this range allows to compensate the total magnetic angular momentum of the Gd and Co sublayers at a compensation temperature $T_\tau \approx 219$ K which is slightly higher than the magnetic moment compensation temperature at $T_\mathrm{M} = 210$ K. Our data suggests the existence of DMI in Co arising at the Co/Gd interface which effective field is opposite to that of the DMI at the Pt/Co interface. Based on findings of our 1D model, we develop a novel method to measure heating effects in a two-material based magnetic bi-layer system and prove an efficiency boost due the exchange coupling torque at T_τ

MA 10: Skyrmions I (joint session MA/KFM/TT)

Time: Monday 15:00–18:30 Location: EB 301

Topical Talk MA 10.1 Mon 15:00 EB 301

Structure, Energetics, and Deterministic Writing of Skyrmions in Thin Film Ferromagnets — •Felix Büttner — MIT, Cambridge, MA, USA

Room temperature skyrmions were recently observed in magnetic multilayer systems [1-4], most of them in materials with sizable Dyzaloshinskii-Moriya interaction (DMI). In this talk, I will present a unified theory that analytically describes the energy of such skyrmions, including stray fields [1]. We can now rigorously define two types of skyrmions, "stray field skyrmions" and "DMI skyrmions". DMI skyrmions can be sub-10 nm at zero field and room temperature and moved with velocities exceeding 1000 m/s at 10^{12} A/m^2.

Experimentally, I will show that skyrmions can be nucleated by spin-orbit torque current pulses without any applied fields [2]. The nucleation mechanism is robust, ultra-fast (sub-nanosecond), and extremely easy to implement. I will discuss the mechanism of the skyrmion generation and explain why DMI can replace the need for in-plane fields.

[1] Büttner et al., Nat Phys. 11, 225 (2015). [2] Woo et al., Nat Mater. 15, 501 (2016). [3] Moreau-Luchaire et al., Nat Nano. 11, 444 (2016). [4] Boulle et al., Nat Nano. 11, 449 (2016). [5] Büttner et al., arXiv:1704.08489 [6] Büttner et al., Nat Nano. 12, 1040 (2017).

MA 10.2 Mon 15:30 EB 301

Skyrmion bubble size and density control in Ta/CoFeB/MgO wedges — •Christian Denker[1], Sören Nielsen[2], Enno Lage[2], Jeffrey McCord[2], and Markus Münzenberg[1] — [1]Institut für Physik, Universität Greifswald, Germany — [2]Nanoscale Magnetic Materials - Magnetic Domains, Institute for Materials Science, Universität Kiel, Germany

After the observation of skyrmion bubbles at room temperature in Ta/CoFeB/TaO$_x$ layers by A. Hoffmann's group, skyrmions have been found in various heavy metal/ferromagnet/oxide systems. For skyrmion generation and detection by magnetic tunnel junctions (MTJ), the Ta/CoFeB/MgO system is appealing due to high TMR ratios and its technological maturity. As a starting point typical MTJ bottom electrodes and barriers (5 nm Ta/x CoFeB/3 nm MgO) trilayers with an optional Ru capping were deposited by e-beam evaporation (MgO, Ru) and magnetron sputtering (Ta, CoFeB). We will present our results on skyrmion bubbles observed by magneto-optical Kerr effect microscopy as function of continuous variation of CoFeB thickness. The in- to out-of-plane transition for the magnetic anisotropy is found at about $x = 1.4$ nm. At slightly thinner CoFeB thicknesses skyrmions can be nucleated. Their size can be as small as 300 nm. The influence of CoFeB composition and annealing temperature on the skyrmion formation, as well as skyrmion stability will be discussed.

MA 10.3 Mon 15:45 EB 301

Small angle neutron scattering experiments of skyrmions far from equilibrium — •Alfonso Chacon[1], Marco Halder[1], Andreas Bauer[1], Wolfgang Simeth[1], André Heinemann[2], Sebastian Mühlbauer[2], and Christian Pfleiderer[1] — [1]Physik Department, Technische Universität München, Germany — [2]Heinz Maier-Leibnitz Zentrum, Garching, Germany

The prospect of the application of magnetic skyrmions in next-generation spintronic devices has recently created substantial scientific interest in this type of magnetic order. Stabilized by thermal fluctuations closed to the paramagnetic order, skyrmion lattices in cubic chiral magnets are constrained to a small window a few Kelvin wide. Recent developments have demonstrated how to expand this regime down to low temperatures by means of supercooling, electrical fields, or uniaxial pressure. Thus, it is possible to study this topological type of magnetism far from equilibrium. We report detailed small angle neutron scattering experiments on skyrmion lattices in B20 compounds at very low temperatures stabilized through fast cooling and discuss the role of disorder and magnetocrystalline anisotropies in their stabilization.

MA 10.4 Mon 16:00 EB 301

Entropy limited topological protection of skyrmions in Fe$_{1-x}$Co$_x$Si — Johannes Wild[1], •Thomas Meier[1], Simon Pöllath[1], Matthias Kronseder[1], Andreas Bauer[2], Alfonso Chacon[2], Marco Halder[2], Marco Schowalter[3], Andreas Rosenauer[3], Josef Zweck[1], Jan Müller[4], Achim Rosch[4], Christian Pfleiderer[2], and Christian Back[1] — [1]Institut für experimentelle und angewandte Physik, Universität Regensburg — [2]Physik-Department, Technische Universität München — [3]Institut für Festkörperphysik, Universität Bremen — [4]Institut für Theoretische Physik, Universität zu Köln

Topologically protected magnetic textures in materials with broken inversion symmetry are considered as future high-density data storage media. The life time of these textures therefore plays a crucial role for data retention. We have used Lorentz transmission electron microscopy to infer the energetics of the topological decay of magnetic skyrmions far from equilibrium in the chiral magnet Fe$_{1-x}$Co$_x$Si. We investigated the decay of a lattice of sykrmions at different magnetic fields and temperatures by imaging the magnetic configuration of the system in real-time with a high speed camera. We observed that the skyrmion life time τ extracted from these movies depends exponentially on temperature following an Arrhenius law, $\tau \propto \tau_0 \exp(\Delta E/k_\mathrm{B}T)$.

The prefactor τ_0 of this Arrhenius law changes by more than 30 orders of magnitude for small changes of magnetic field reflecting a substantial reduction of the life time of skyrmions by entropic effects and thus an extreme case of enthalpy-entropy compensation.

MA 10.5 Mon 16:15 EB 301

Magnetotransport and Hall effect of MnSi thin film under pressure — •David Schroeter[1], Stefan Süllow[1], Dirk Menzel[1], Hiroyuki Hidaka[2], Hideto Okuyama[2], and Hiroshi Amitsuka[2] — [1]Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany — [2]Graduate School of Science, Hokkaido University Sapporo, Japan

In the recent years thin films of the B20 compound MnSi became subject of great interest, since the magnetic properties of bulk MnSi are modified due to the dimensional reduction and the uniaxial anisotropy with a suspected stabilized skyrmionic phase [1]. In comparison to bulk material MnSi thin film shows an enhanced ordering parameter with ongoing research about the nature of the magnetic order in thin film state [2].

The ordering temperature and critical fields of MnSi decrease with applied hydrostatic pressure, with thin film material recovering bulk values for the transition temperature at $p_{recover} \approx 2.3$ GPa and a qualitatively similar behavior to bulk MnSi with respect to the ordering temperature above $p_{recover}$ [3]. We present magnetotransport and Hall effect measurements on MnSi thin films under applied pressure of up to around 4 GPa and discuss our results concerning the magnetic phase diagram under pressure.

[1] A. B. Butenko et al., Phys. Rev. B 82, 052403 (2010).
[2] M. N. Wilson et al., Phys. Rev. B 86, 144420 (2012).
[3] J. Engelke et al., Phys. Rev. B 89, 144413 (2014).

MA 10.6 Mon 16:30 EB 301

Magnetic anisotropy in the itinerant helimagnet MnSi — •Schorsch M. Sauther[1], Andreas Bauer[1], Dirk Grundler[2], Christian Pfleiderer[1], and Marc A. Wilde[1] — [1]Phys.-Dep. E51, TU München — [2]LMGN, IMX, STI, EPF Lausanne

We report torque magnetometry in Manganese silicide (MnSi). In our experiment, we employ cantilever magnetometry in a 2D magnetic field $\vec{B} = B \cdot (\sin\varphi \quad \cos\varphi)$ to measure the torque τ resulting from the anisotropic magnetization $\vec{M}_\perp$ of a high-quality, single-crystalline bulk sample of MnSi. The angular dependence $\tau(\varphi)$ displays distinct oscillations with differently pronounced extrema. The oscillation amplitude between several extrema does not saturate for our maximum field of 4.5 T. In the field dependence $\tau(B)$ we observe an unexpected hysteresis above H_{c2}. Furthermore, the hysteretic behavior below H_{c2} changes drastically with temperature below T_c. We utilize our observations to determine the anisotropy constants and discuss our results in the context of complementary experiments[1].

[1] A. Bauer *et al.*, Phys. Rev. B **95**, 024429 (2017)

15 min break

MA 10.7 Mon 17:00 EB 301

Inelastic neutron scattering studies of magnons in the field polarized, conical and Skyrmion phase of MnSi — •Lukas Beddrich[1], Tobias Weber[3], Robert Georgii[1,2], and Peter Böni[1] — [1]Physik-Department E21, Technische Universität München, 85748 Garching, Germany — [2]Heinz Maier-Leibnitz Zentrum (MLZ), Technische Universität München, 85748 Garching, Germany — [3]Institut Laue-Langevin (ILL), 38000 Grenoble, France

Cubic chiral magnets, such as MnSi, are prototypical systems for the investigation of various spin structures. They are stabilized by the Dzyaloshinsky-Moriya interaction (DMI), which also gives rise to a universal magnon dispersion [1], [2].

Recently, the effect of non-reciprocal spin wave excitations, which generally emerge from the lack of inversion symmetry, were intensively studied in the field-polarized and helimagnetic phase of MnSi with inelastic neutron scattering [3]. Due to the excellent compatibility between the low-energy theory and the comprehensive measurements, we currently apply a related approach to describe the magnetic excitations found in the skyrmion phase.

[1] M. Janoschek et al. *Phys. Rev. B*, 81:214436, Jun 2010 doi:10.1103/PhysRevB.81.214436

[2] M. Kugler et al. *Phys. Rev. Lett.*, 115:097203, Aug 2015. doi:10.1103/PhysRevLett.115.097203

[3] T. Weber et al. *submitted for publication*

MA 10.8 Mon 17:15 EB 301

Orientation dependence of the magnetic phase diagram of the chiral magnet Cu_2OSeO_3 — •Marco Halder[1], Alfonso Chacon[1], Andreas Bauer[1], Helmuth Berger[2], and Christian Pfleiderer[1] — [1]Technische Universität München, Physik-Department E21, D-85748 Garching, Germany — [2]École Polytechnique Fédérale de Lausanne, Crystal Growth Facility, CH-1015 Lausanne, Switzerland

In recent years, the cubic chiral insulator Cu_2OSeO_3 attracted great scientific interest, combing the skyrmion lattice phase with strong magneto-electric coupling. We report a comprehensive study of the magnetic properties of single-crystal Cu_2OSeO_3 by means of measurements of the magnetization, ac susceptibility, and specific heat, in particular tracking the influence of crystal orientation, cooling history and demagnetizing effects on the formation of skyrmion order.

MA 10.9 Mon 17:30 EB 301

Time resolved Lorentz-TEM measurements of dynamical skyrmion lattice defects in Cu_2OSeO_3 — •Simon Pöllath[1], Johannes Wild[1], Lukas Heinen[2], Thomas Meier[1], Matthias Kronseder[1], Leonard Tutsch[1], Andreas Bauer[3], Helmuth Berger[4], Christian Pfleiderer[3], Josef Zweck[1], Achim Rosch[2], and Christian Back[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Deutschland — [2]Institut für Theoretische Physik, Universität zu Köln, Deutschland — [3]Physik-Department, Technische Universität München, Deutschland — [4]Crystal Growth Facility, École Polytechnique Fédérale de Lausanne, Schweiz

We report non-stroboscopic time resolved Lorentz-Transmission-Electron-Microscopy (LTEM) measurements of skyrmion lattice defects in the chiral magnet Cu_2OSeO_3. The multiferroic insulator hosts a hexagonal skyrmion lattice which can be observed in real space using LTEM. It is known, that the radial temperature profile caused by the illumination of the sample with the TEM electron beam sets the skyrmion lattice into rotation [1]. We utilize this effect to study the dynamics of defects and grain boundaries that naturally occur during the lattice rotation. The structural and dynamical behaviour of the defects is similar to that of 2D hexagonal particle lattices and therefore the particle character of the skyrmion in its lattice phase is stressed by our findings [2].

[1] Mochizuki, M. et al. Nat. mater. 13.3 (2014): 241-246
[2] Pöllath S, et al. PRL 118.20 (2017): 207205

MA 10.10 Mon 17:45 EB 301

Large-scale *ab initio* investigations of complex magnetic textures — •Marcel Bornemann, Sergii Grytsiuk, Paul F. Baumeister, Phivos Mavropoulos, Nikolai S. Kiselev, Samir Lounis, Rudolf Zeller, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

We have developed a unique electronic structure code, KKR*nano* [1], specifically designed for petaFLOP computing. Our method scales linearly with the number of atoms, so that we can realize system sizes of up to half a million atoms in a unit cell. Recently, we implemented a relativistic generalization of the algorithm enabling the calculation of complex non-collinear magnetic structures in real space.

We present two applications: (i) In the helimagnet B20-MnGe different experimental groups have observed either a spin spiral in [001] direction or a 3Q-state composed of three spin spirals [2,3]. We present an *ab initio* comparison of both states. (ii) We performed a large-scale evaluation of low-lying thermal excitations, so-called “nodons”, in Cr which could explain the formation of a spin density wave in this system [4].

Simulations were performed with computing resources granted by JARA-HPC, Forschungszentrum Jülich and HLRS in Stuttgart.

[1] A. Thiess *et al.*, Phys. Rev. B **85**, 235103 (2012).
[2] O.L. Makarova *et al.*, Phys. Rev. B **85**, 205205 (2012).
[3] T. Tanigaki *et al.*, Nano Lett. **15**, 5438 (2015).
[4] V. Vanhoof *et al.*, Phys. Rev. B **80**, 184420 (2009).

MA 10.11 Mon 18:00 EB 301

Giant structural response of Dzyaloshinskii-Moriya interaction in MnGe B20 compounds — •Sergii Grytsiuk, Marcel Bornemann, Markus Hoffmann, Bernd Zimmermann, Phivos Mavropoulos, Gustav Bihlmayer, and Stefan Blügel

— Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Non-centrosymmetric cubic B20 materials are currently under intensive investigation. An important feature of these materials is the competition between the antisymmetric Dzyaloshinskii-Moriya interaction (DMI) and the symmetric exchange interaction resulting in a rich variety of magnetic phases with respect to temperature, magnetic fields, material compositions and geometries. The possibility of engineering chiral structures and the effective switching between different magnetic phases requires the investigation of possible factors that influence the strength of the magnetic interactions. In this work, we show by first-principles calculations based on DFT that under pressure magnetic and structural properties of MnGe reveal a hysteretic behavior near the state where energies of high and low spin states coincide. We observe that pressure strongly enhances the DMI (by a factor 5), while the spin-stiffness gets smaller. In order to understand such giant enhancement of the micromagnetic DMI we computed atomistic DMI vectors. Surprisingly, the absolute value of the DMI vectors do not depend significantly on the lattice parameter and the enhancement of micromagnetic DMI stems mainly from the change of the DMI vectors' orientation with respect to bonds between Mn atoms.

MA 10.12 Mon 18:15 EB 301

Spin-orbit coupling effects in magnetic and response properties of B20 $A_{1-x}B_xGe$ alloys (A, B = Mn, Fe, Co, Rh) — •Sergiy Mankovsky[1], Sebastian Wimmer[1], Svitlana Polesya[1], Nicolas Martin[2], Isabelle Mirebeau[2], and Hubert Ebert[1] — [1]Dept. Chemistry, LMU Munich, D-81377 Munich, Germany — [2]Lab. Léon Brillouin, CEA, CNRS, Uni. Paris-Saclay, France

The composition-dependence of the isotropic exchange (J_{ij}) and Dzyaloshinskii-Moriya interaction (DMI) ($\vec{D}_{ij}$) of $Mn_{1-x}Fe_xGe$, $Mn_{1-x}Rh_xGe$, $Mn_{1-x}Co_xGe$ and $Fe_{1-x}Co_xGe$ B20 alloys have been investigated by first-principles calculations using the relativistic multiple scattering Korringa-Kohn-Rostoker (KKR) formalism. The $D^{\alpha\alpha}$ ($\alpha = x, y, z$) elements of the DMI tensor exhibit a strong dependence on the composition, changing sign at $x \approx 0.85$ in $Mn_{1-x}Fe_xGe$ and at $x \approx 0.5$ in $Fe_{1-x}Co_xGe$, in line with previous theoretical calculations as well as with experimental results. The spin-orbit torque (SOT), anomalous and spin Hall conductivities (AHC and SHC, respectively) of $Mn_{1-x}Fe_xGe$ alloys have been investigated. A sign change at $x \approx 0.5$ is predicted for the Fermi sea contribution to the SOT, as this is closely related to the DMI. In the case of anomalous and spin Hall effects it is shown that the calculated Fermi sea contributions are rather small and the composition-dependence of these effects are determined mainly by the electronic states at the Fermi level. The spin-orbit-induced scattering mechanisms responsible for both effects are suggested to cause the minimum of the AHC and the sign change of the SHC.

MA 11: Ultrafast magnetism II

Time: Monday 15:00–17:45 Location: EB 407

MA 11.1 Mon 15:00 EB 407

Ultrafast Dynamics of Spin and Orbital Moments upon Demagnetization in GdFeCo alloys — •Martin Hennecke[1], Ilie Radu[1], Radu Abrudan[2], Torsten Kachel[2], Karsten Holldack[2], Rolf Mitzner[2], Christian Schüssler-Langeheine[2], Arata Tsukamoto[3], and Stefan Eisebitt[1] — [1]Max-Born-Institut, Berlin, Germany — [2]Helmholtz-Zentrum Berlin, Germany — [3]College of Science and Technology, Nihon University, Funabashi, Chiba, Japan

Recent studies of ferrimagnetic GdFeCo alloys have revealed an ultrafast laser-induced magnetization reversal mediated by a transient ferromagnetic-like state [1]; such switching was purely thermally-driven without the need of any other external stimulus [2]. However, the ultrafast angular momentum transfer from and into the spin system during demagnetization and switching events still remains unclear.

Here, we report on time-resolved XMCD measurements performed at the slicing facility of BESSY II that aim at revealing the angular momentum flow during femtosecond laser-induced demagnetization of ferrimagnetic GdFeCo alloy. The magneto-optical sum rules analysis of the fs-XMCD data allowed us to monitor and disentangle the dynamics of elemental spin and orbital moments at Fe and Gd sites. Within the experimental accuracy, we observe a non-equal magnitude change of spin and orbital momenta on Fe sites during the first hundreds of femtoseconds which suggests a direct transfer of angular momentum to the lattice.

[1] I. Radu et al., Nature 472, 205-208 (2011)
[2] T. Ostler et al., Nature Communications 3, 666 (2012)

MA 11.2 Mon 15:15 EB 407

Energy-resolved ultrafast charge, spin and orbital dynamics in [Co/Pd] multilayers — •Loïc Le Guyader[1,2], Daniel Higley[1], Tianmin Liu[1], Zhao Chen[1], Tyler Chase[1], Patrick Granitzka[1], Giacomo Coslovich[1], Alberto Lutman[1], Georgi Dakovski[1], William Schlotter[1], Padraic Shafer[3], Elke Arenholz[3], Olav Hellwig[4], Stefano Bonetti[5], Matteo Pancaldi[5], Mark Lalieu[6], Bert Koopmans[6], Joachim Stöhr[1], Alexander Reid[1], and Hermann Dürr[1] — [1]SLAC, Menlo Park, USA — [2]European XFEL GmbH, Schenefel, Germany — [3]ALS, LBNL, Berkley, USA — [4]TU Chemnitz and HZDR, Germany — [5]Stockholm University, Sweden — [6]TU Eindhoven, The Netherlands

The ultrafast demagnetization is a fundamental problem of modern magnetism, with its microscopic origin remaining intensely debated. Particularly, the role played by the spin-orbit interaction in the moment dissipation to the lattice and that of the exchange interaction in the collapse of long-range order call for measurements capable of resolving the charge, spin and the orbital moment dynamics energy resolved. Here we use soft X-ray Absorption Spectroscopy (XAS) with femtosecond X-ray produced by the Linac Coherent Light Source (LCLS) to probe charge and band structure dynamics around the Fermi energy E_F in a [Co/Pd] magnetic multilayer. Comparing XAS changes at both L_3 and L_2 absorption edges below and above E_F highlights the role played by the $3d_{5/2}$ states. Using X-ray Magnetic Circular Dichroism (XMCD), we further discuss the spin and orbital moment dynamics with respect to the energy resolved charge dynamics.

MA 11.3 Mon 15:30 EB 407

Ultrafast demagnetization in Co/Pt multilayers probed by mSAXS at the Co L-edge — •Matthias Riepp[1], Leonard Müller[1], André Philippi-Kobs[1], Wojciech Roseker[1], Robert Frömter[2], Emanuele Pedersoli[3], Flavio Capotondi[3], Maya Kiskinova[3], Hans Peter Oepen[2], and Gerhard Grübel[1] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestraße 85, 22607 Hamburg, Germany — [2]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]Elettra-Sincrotrone Trieste S.C.p.A. di interesse nazionale, Strada Statale 14 - km 163,5 in AREA Science Park, 34149 Basovizza, Trieste, Italy

Ultrafast demagnetization of thin magnetic films due to an optical pump is a phenomenon which is still discussed highly controversial. Here, to probe the response of magnetization on a nanometer length as well as on a femtosecond time scale, a resonant magnetic small-angle X-ray scattering (mSAXS) experiment was employed at the DiProI beamline at FERMI. Co/Pt multilayers with perpendicular magnetic anisotropy and a maze-domain pattern were investigated. Changes of the magnetic state due to IR-laser irradiation were detected as a function of pump probe delay time. In this experiment we have used soft X-rays tuned to the Co L_3-edge (1.59 nm) by using FERMI's FEL-2. FERMI was tuned to provide linear polarized light at a wavelength of 4.78 nm in the fundamental so that the third harmonic of this radiation was in resonance with the Co L-edge. By comparing the results with the ones obtained using the Co M-edge (20.8 nm), the role of super-diffusive spin currents on the demagnetization is discussed.

MA 11.4 Mon 15:45 EB 407

Magnetization reversal and demagnetization dynamics of Co/Pt multilayers with circularly polarized laser pulses — •Umut Parlak, Roman Adam, Seung-gi Gang, Moritz Plötzing, Daniel E. Bürgler, and Claus M. Schneider — Peter Grünberg Institut, PGI-6, Research Centre Jülich, 52425, Jülich, Germany

All-optical control of magnetization has attracted great interest since it allows magnetization reversal in the absence of applied magnetic fields. Recent studies showed that deterministic magnetization reversal requires accumulation of many pulses in ferromagnetic layers unlike the ferrimagnetic layers which can be switched with single pulses. We present a study of all-optical magnetization reversal of ferromagnetic $[Co/Pt]_N$ multilayers as a function of varying beam parameters. The multilayers were illuminated by a femtosecond laser beam with a wavelength of 800 nm and a repetition rate between 0.01 and 1 kHz. Our results indicate that all-optical magnetization reversal in $[Co/Pt]_N$ multilayers is helicity dependent and the helicity-induced reversal probability scales with the number of pulses per unit area. Single pulses have no effect on magnetism as long as the laser fluence is kept below the demagnetization threshold. For pulses above this threshold, we employed time resolved magneto-optical Kerr effect magnetometry and investigated the ultrafast demagnetization process under exposure of circularly polarized single pulses.

MA 11.5 Mon 16:00 EB 407

Modelling of spin-resolved ARPES experiments on ultra-fast demagnetisation on the basis of the one-step model of photoemission — •Voicu Popescu[1], Jan Minàr[2], Jürgen Braun[1], and Hubert Ebert[1] — [1]Department Chemie, Ludwig Maximilian University, Munich, Germany — [2]University of West Bohemia, New Technologies Research Centre, Plzeň, Czech Republic

The ultra-fast demagnetisation caused by a strong laser pulse was investigated recently by Eich *et al.* [1] by spin and angle-resolved photo emission (ARPES) experiments on the elemental ferromagnet Co [1]. To interpret the dependence of the observed effective exchange splitting on the delay time of this pump-probe experiment two different models were considered: the first one assumes a plain reduction of the exchange splitting in the spirit of the Stoner model, while the second one accounts for a magnon-mediated band-mirroring subsequent to the excitation. The experimental data seem to favour the second model. The present contribution seeks to check this interpretation of the experimental data by performing ARPES calculations for ferromagnetic Fe and Co using the one-step model of photo-emission within the framework of the spin-polarised relativistic Korringa-Kohn-Rostoker method. To allow for a rather direct comparison with experiment both scenarios were modelled as close as possible. The discussion of the resulting ARPES spectra is accompanied by an analysis of the underlying electronic structure.

[1] S. Eich *et al.* Science Advances **3**, e1602094 (2017)

MA 11.6 Mon 16:15 EB 407

Magnetization dynamics during FeRh phase transition investigated with Time-Resolved X-ray Photoemission Spectroscopy — •F. Pressacco[1,2], V. Uhlir[3], M. Gatti[4,5], J. A. Arregi[3], A. Bendounan[6], F. Sirotti[4,6], and W. Wurth[2,7] — [1]CUI, Hamburg — [2]Dep. Physik CFEL Laser Science, Uni. Hamburg — [3]CEITEC BUT, Czech Republic — [4]LPMC, École Polytechnique, France — [5]European Theoretical Spectroscopy Facility (ETSF) — [6]Synchrotron SOLEIL, France — [7]DESY Photon Science, Hamburg

Direct investigation of the electronic structure by time-resolved photoemission is a powerful tool to follow fast modifications of the physical properties of a system. Here we present a Time Resolved X-ray Photoelectron Spectroscopy (TR-XPS) study of the metamagnetic phase transition induced by femtosecond laser excitation in FeRh epitaxial layers. FeRh is a particularly interesting system due to a first-order phase transition taking place at ∼400 K from an antiferromagnetic phase to a ferromagnetic phase (FM), which induces strong modifications of the electronic structure. In particular we observe the formation of a sharp spin-polarized peak close to the Fermi edge. We have measured the appearance of the peak after a 50 fs laser excitation and followed the onset of the FM phase triggered by the optical pulse. Moreover, by comparing the extracted electronic temperature to the intensity of the FM peak, we could show that the FM phase persists at the surface also when the system is expected to be antiferromagnetic. Ab initio density functional theory calculations associate the structure at the Fermi level to Fe 3d empty states.

15 minutes break

MA 11.7 Mon 16:45 EB 407

Influence of the stoichiometry in ferromagnetic alloys on the ultrafast demagnetization — •Simon Häuser[1], Moritz Hofherr[1], Jurij Urbancic[1], Sakshath Sadashivaiah[1], Sebastian Weber[1], Justin Shaw[2], Tom Silva[2], Hans Nembach[3], Daniel Steil[2], Henry Kapteyn[3], Margaret Murnane[3], Mirko Cinchetti[4], Bärbel Rethfeld[1], Benjamin Stadtmüller[1], Stefan Mathias[2], and Martin Aeschlimann[1] — [1]University of Kaiserslautern, Erwin-Schroedinger Strasse 46, 67663 Kaiserslautern, Germany — [2]Georg-August-Universität Göttingen, I. Physikalisches Institut, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany — [3]Department of Physics and JILA, University of Colorado and NIST, Boulder, CO 80309, USA — [4]Experimentelle Physik VI, Technische Universität Dortmund, 44221 Dortmund, Germany

We investigate time- and element-resolved the fs demagnetization dynamics in a ferromagnetic Fe50Ni50 alloy using a transverse magnetooptical Kerr effect experiment at the M-edge. After the optical excitation, we observe an instant response of the Fe subsystem while the onset of the Ni demagnetization is delayed by 90fs. While this result is in qualitatively agreement to previous findings for permalloy (Fe20Ni80), the time different between the onsets of demagnetization of Ni and Fe is clearly larger for Fe50Ni50 compared to Fe20Ni80. Our experimental findings will be compared to theoretical model simulations which allows us to gain insight into the role of the transient Ni-Fe exchange coupling for the ultrafast demagnetization dynamics.

MA 11.8 Mon 17:00 EB 407

All-optical magnetization switching of FePt nanoparticles by fs laser pulses — •D. Hinzke[1], T. Knippenberg[1], M. Berritta[2], R. Mondal[1,2], R. John[3], J. Walowski[3], C. Müller[4], J. McCord[4], P. Oppeneer[2], M. Münzenberg[3], and U. Nowak[1] — [1]Universität Konstanz — [2]Uppsala University — [3]Universität Greifswald — [4]Universität Kiel

Helicity-dependent all-optical switching (HD-AOS) caused solely by the effect of an ultrafast laser pulse was not only demonstrated for ferrimagnets [1] but also for layered, synthetic ferrimagnets [2] and simple ferromagnets [3]. We study HD-AOS in FePt nanograins numerically by using a complete multiscale model [4]. In our simulation it is possible to distinguish thermal and non-thermal contributions to the HD-AOS.

One of our findings is that a principle difference between magnetic circular dichroism (MCD) and inverse Faraday effect (IFE) assisted switching is the helicity-dependent heating. MCD only leads to a stochastic demagnetization process and, therefore, deterministic single-shot magnetization switching is not possible. On the contrary, an additional magnetization contribution is provided by the IFE that supports deterministic magnetization reversal. We investigate the switching probability of single FePt grains as a function of laser power and number of consecutive laser shots.

[1] K. Vahaplar *et al*, Phys. Rev. Lett. **103**, 117201 (2009) [2] S. Mangin *et al*, Nat. Materials **13**, 287 (2014) [3] C.-H. Lambert *et al*, Science (345), 1337 (2014) [4] R. John *et al*, Sci. Rep. **7**, 4114 (2017)

MA 11.9 Mon 17:15 EB 407

All optical switching and ultrafast magnetization dynamics in doped FePt thin films — •Martin Stiehl[1], Nataliia Safonova[2], Benjamin Stadtmüller[1,3], Manfred Albrecht[2], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany — [2]Institute for Physics, University of Augsburg, Universitätsstraße 1 Nord, 86159 Augsburg, Germany — [3]Graduate School Materials Science in Mainz, Staudinger Weg 9, 55128 Mainz, Germany

The speed of magnetic data storage and information processing is particularly important for device performance but presently limited to a few nanoseconds. In this regard all-optical switching (AOS) is a highly promising effect which allows to switch the magnetization within a few tens of ps.

Here, we focus on the AOS phenomena and the corresponding fs magnetization dynamics in FePt thin films doped with Tb using all optical detection schemes based on the time-resolved magneto-optical Kerr effect. For a Tb concentration of 11% and linear polarization of the optical excitation, we observe a single-shot magnetization reversal within the first ps which lasts over 20ps without indications of remagnetization. We will compare results for different Tb concentrations to gain insight into the role of the dopant for the observed magnetization reversal.

MA 11.10 Mon 17:30 EB 407

All Optical Switching in Ferromagnets: A Dynamical Model Study — •Christiane Scholl — University of Kaiserslautern

We present a microscopic calculation of the spin dynamics due to excitation with off-resonant and close-to-resonance circularly polarized optical fields in a mean-field ferromagnetic model system including spin-orbit-coupling, incoherent nonlinear effects and electronic redistribution processes.

Within the framework of the model, we calculate the evolution of the magnetization and show that, for certain excitation conditions, a polarization dependent switching of the magnetization occurs. In this talk, we clarify the respective contributions of the Inverse Faraday Effect [1,2] and the Spin-selective Optical Stark effect (spin-OSE) as introduced in [3]. We also discuss the effect of electronic heating and the role of off-resonant and nearly-resonant transitions.

[1] A. Kirilyuk, A. V. Kimel and T. Rasing, Rev. Mod. Phys. 82, 2731 (2010)

[2] M. Berritta, R. Mondal, K. Carva, P. M. Oppeneer, Phys. Rev. Lett. 117, 137203 (2016)

[3] A. Qaiumzadeh, G.E.W. Bauer and A. Brataas, Phys. Rev. B 88, 064416 (2013)

MA 12: Superconductivity – Topological Defects in Superconductors and Magnets (joint session TT/MA)

Time: Monday 15:00–17:45 Location: HFT-FT 101

MA 12.1 Mon 15:00 HFT-FT 101

Topological domain walls in helimagnets — •Laura Köhler[1], Peggy Schönherr[2], Jan Müller[3], Naoya Kanazawa[4], Yoshinori Tokura[4,5], Achim Rosch[3], Dennis Meier[6], and Markus Garst[1] — [1]Institut für Theoretische Physik, TU Dresden, Dresden, Germany — [2]Department of Materials, ETH Zürich, Zürich, Switzerland — [3]Institut für Theoretische Physik, Universität zu Köln, Köln, Germany — [4]Department of Applied Physics, University of Tokyo, Tokyo, Japan — [5]RIKEN Center for Emergent Matter Science (CEMS), Wako, Japan — [6]Department of Materials Science and Engineering, NTNU, Trondheim, Norway

The Dzyaloshinskii-Moriya interaction in chiral magnets stabilizes a magnetic helix with a wavelength set by the spin-orbit coupling. We study domain walls of helimagnetic order both theoretically and experimentally using micromagnetic simulations and magnetic force microscopy studies on surfaces of FeGe. We find that such domain walls are distinctly different from those in ferromagnets and rather similar to grain boundaries of liquid crystals. Three types of domain walls are realized depending on the relative domain orientation: a curvature wall, a zig-zag disclination wall and a dislocation wall. Disclinations are vortex defects in the helix axis orientation, and they can be combined to form dislocations. We discuss the topological skyrmion charge associated with these dislocations which can be finite. This leads to an emergent electrodynamics and thus a coupling to spin currents as well as to a contribution to the topological Hall effect.

[1] P. Schönherr et al. arXiv1704.06288 (2017).

MA 12.2 Mon 15:15 HFT-FT 101

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

Complex spin textures, like helical spin spirals with a fixed wavelength, can occur due to chiral magnetic interactions. Chiral magnets are a striking nanoscopic analog to liquid crystals, possessing lamellar phases and ordered topological defects. Defects are of great importance as they strongly influence order and mobility of the spin system. Here, we present magnetic force microscopy measurements in combination with micromagnetic simulations, discussing the dynamics and interactions of 1D and 2D objects with non-trivial topology in the helimagnetic phase of FeGe. We show that the local magnetization dynamics are strongly influenced by depinning and subsequent motion of edge dislocations (1D). Their motion is part of a slow relaxation process, having profound impact on the formation of the helical ground state. Other 1D objects that play an important role for the micromagnetism are so-called π disclinations, which can form chains and build domain walls that are distinctly different from classical antiferro- and ferromagnetic domain walls. Thus, our microscopy data reveal a new multitude of magnetic nano-objects with non-trivial topology going beyond the previously discussed skyrmions.

MA 12.3 Mon 15:30 HFT-FT 101

Mechanisms of nucleation of chiral bobbers in helical magnets — Fengshan Zheng[1,2], •Filipp N. Rybakov[3], Aleksandr B. Borisov[4], Dongsheng Song[5], Shasha Wang[6,7], Zi-An Li[8], Haifeng Du[6,7], Nikolai S. Kiselev[2], Jan Caron[1,2], András Kovács[1,2], Mingliang Tian[6,7], Yuheng Zhang[6,7], Stefan Blügel[2], and Rafal E. Dunin-Borkowski[1,2] — [1]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, Germany — [2]Peter Grünberg Institut, Forschungszentrum Jülich, Germany — [3]Department of Physics, KTH-Royal Institute of Technology, Stockholm, Sweden — [4]M.N. Miheev Institute of Metal Physics, Ekaterinburg, Russia — [5]National Center for Electron Microscopy in Beijing, Tsinghua University, China — [6]High Magnetic Field Laboratory, Hefei, China — [7]Collaborative Innovation Center of Advanced Microstructures, Nanjing University, China — [8]Institute of Physics, Beijing, China

Magnetic chiral bobbers are stable particlelike states that represent a skyrmion texture combined with Bloch point [1]. Recently they were discovered experimentally in B20-type FeGe compound [2]. Here we present the detailed description on different mechanisms of nucleation of chiral bobbers which were revealed theoretically and then confirmed in experiments with FeGe specimens. The discussed mechanisms represent general phenomena and can be applied to a variety of other chiral magnetic compounds.

[1] F.N. Rybakov et al. PRL **115**, 117201 (2015).

[2] F. Zheng et al. arXiv:1706.04654 (2017).

MA 12.4 Mon 15:45 HFT-FT 101

Skyrmion optical creation/annihilation in a chiral magnet — •Gabriele Berruto[1], Ivan Madan[1], Yoshie Murooka[1], Giovanni Maria Vanacore[1], Enrico Pomarico[1], Damien McGrouther[2], Yoshihiko Togawa[2], Heinrik Rønnow[1], and Fabrizio Carbone[1] — [1]Institute of Physics, EPFL, Lausanne, Switzerland — [2]SUPA, University of Glasgow, United Kingdom

We show that single light pulses of different duration and color can create and annihilate skyrmions for a broad range of parameters in the magnetic phase diagram of a 50 nm-thick slab of FeGe, a prototypical chiral magnet. Using a combination of camera-rate and ns pump-probe cryo-Lorentz Transmission Electron Microscopy, we directly resolve the spatio-temporal evolution of the magnetization ensuing (fs and ns) optical excitation. When we excite optically the skyrmion lattice, its structural parameters are not modified, only the magnetization being affected: it transiently decreases, and recovers to the initial value over long (μs) time scales, reflecting the important role of the cooling rate of the system. Contrary to previously reported cases in different systems, in our experiment the skyrmions are not created via a transient demagnetized (paramagnetic) state. The laser pulses transiently heat the system, driving it into a region of the phase diagram where the appearance of skyrmions is strongly favored, but still staying far below the Curie temperature. The system then supercools down to base temperature, and skyrmions remain frozen into their (meta)stable state. The skyrmion topological charge is injected from geometric edges, defects, and magnetic boundaries.

MA 12.5 Mon 16:00 HFT-FT 101

Coupling of magnetic flux quanta to tunable domain structures in superconductor/ferromagnet bilayers with varying Dzyaloshinskii-Moriya interaction — •Palermo Xavier[1], Samokhvalov Alexei[3], Collin Sophie[1], Bouzehouane Karim[1], Santamaria Jacobo[1], Sander Anke[1], Reyren Nicolas[1], Cros Vincent[1], Buzdin Alexander[2], and Villegas Javier E.[1] — [1]Unité Mixte de Physique CNRS-Thales, Palaiseau, France — [2]Laboratoire Ondes et Matière d'Aquitaine (LOMA), Talence, France — [3]N.Novgorod, Russia

We study magneto-transport in hybrids combining superconducting films with magnetic multilayers in which varying the stacking sequence (e.g. Co/Pt vs. Ir/Co/Pt) allows tailoring the interfacial Dzyaloshinskii-Moriya interaction, and the characteristics of the magnetic domain structure. The magnetoresistance in the superconducting state shows a strong hysteresis, which is observed during the magnetization reversal and closely follows the reversal details. This behavior is in stark contrast with that expected for a plain superconducting film, and is strongly dependent on the size and morphology of the domain structure (presence of wormlike or skyrmion structures). The results can be understood in terms of mutual interaction between flux quanta and the local magnetization, which modifies vortex nucleation and mobility, and possibly the magnetic structure in the ferromagnets.

Work supported by the ERC grant N 64710 and French ANR grant ANR-15-CE24- 0008-01

MA 12.6 Mon 16:15 HFT-FT 101

Interactions between superconductor-ferromagnet thin films — •Annika Stellhorn[1], Anirban Sarkar[1], Emmanuel Kentzinger[1], Sonja Schröder[1], Grigol Abuladze[1], Markus Waschk[1], Patrick Schöffmann[2], Zhendong Fu[2], Vitaliy Pipich[2], and Thomas Brückel[1,2] — [1]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT, 52425 Jülich GERMANY — [2]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science at MLZ, Lichtenbergstr. 1, 85748 Garching Germany

Interactions at superconductor-ferromagnet (S/F) interfaces have been studied on a prototype Nb (S)/ FePd (F) system. Our goal is to understand the proximity effects of FePd with different strength of perpendicular magnetic anisotropy (PMA) and magnetic domain texture on the superconducting Nb layer. Proximity effects at S/F interfaces with an inhomogeneous magnetic field texture result in various effects, like domain-wall superconductivity and long-ranged triplet cooper pairs in the F-layer, making them good candidates for superconducting spintronics. Epitaxial heterostructures of Nb/FePd are prepared on MgO (001) substrate using Molecular Beam Epitaxy. Magnetic Force Microscopy images of FePd grown by shuttered growth reveal a striped domain structure. Macroscopic magnetization measurements show weak PMA. However, co-deposition of FePd at varying temperatures results in different strength of PMA. Grazing-Incidence-Small-Angle-Neutron-Scattering reveals the depth profile of the magnetization in the heterostructure.

15 min. break.

MA 12.7 Mon 16:45 HFT-FT 101

Giant non-local vortex motion in WC nanowires grown by Ga+ focused ion beam deposition — •Rosa Córdoba[1,2], José María De Teresa[1,2,3], Ricardo Ibarra[2,3], Isabel Guillamón[4], Hermann Suderow[4], Sebastián Vieira[4], and Javier Sesé[2,3] — [1]Instituto de Ciencia de Materiales de Aragón (ICMA), CSIC-UZ, Spain — [2]Departamento de Física de la Materia Condensada, Universidad de Zaragoza, Spain — [3]Laboratorio de Microscopías Avanzadas, Instituto de Nanociencia de Aragón, UZ — [4]Departamento de Física de la Materia Condensada, Universidad Autónoma de Madrid, Spain

In this contribution, we propose an unconventional route to transfer vortices as single particles through long distances (in the micrometers range), within WC nanowires (50 nm in width), taking profit of current-induced non-local vortex motion [1]. By reducing the lateral dimensions of wires near superconducting coherence length of the material, we measured a giant non-local electrical signal which is 40 times higher than those reported for wider wires of other superconductors. Comparing the non-local electrical signal in WC wires of different dimensions, we found that the signal for 50 nm-wide WC nanowires is nearly two orders of magnitude higher than for the 200 nm-wide WC ones. The measured giant non-local signal in the former strongly confirms that the vortex line is more rigid than the vortex lattice in wider wires due to its quasi-1D character and its confinement potential that prevents the transversal vortex displacements.

[1] R. Córdoba et al. manuscript submitted to Applied Physics Letters.

MA 12.8 Mon 17:00 HFT-FT 101

Unusual critical state and vortex commensurability in cuprate superconductors with regular topological defects — •Wolfgang Lang[1], Georg Zechner[1], Kristijan L. Mletschnig[1], Florian Jausner[1], Meirzhan Dosmailov[2], Marius A. Bodea[2], and Johannes D. Pedarnig[2] — [1]University of Vienna, Faculty of Physics, Wien, Austria — [2]Johannes-Kepler-University Linz, Institute of Applied Physics, Linz, Austria

The interaction of vortices with artificial defects in a superconductor is a vibrant topic in experimental and theoretical research, but also important for its prospects of technical applications. The advantage of a higher operation temperature in $YBa_2Cu_3O_{7-\delta}$ (YBCO) is opposed by the demand for advanced nanopatterning methods. To this end, YBCO thin films are irradiated with He^+ ions by shadow projection through a Si stencil mask to create a square array of columnar defect regions of 180 nm diameter and 300 nm lattice constant. Peaks of the critical current as a function of the applied magnetic field reveal the commensurate trapping of vortices in domains near the edges of the sample. Upon ramping an external magnetic field, an unconventional critical state emerges that is characterized by a pronounced hysteresis and different positions of the critical current peaks in virgin and field-saturated down-sweep curves, respectively. Interestingly, the distances of the various peaks in a sweep remain constant and correspond exactly to the matching field. The observations are interpreted as a nonuniform, terrace-like critical state, in which individual domains are occupied by a fixed number of vortices per pinning site.

MA 12.9 Mon 17:15 HFT-FT 101

Vortex motion and change inside the superconducting phase of the ferromagnetic superconductor UCoGe — •Beilun Wu[1], Dai Aoki[2,3], and Jean-Pascal Brison[2] — [1]Universidad Autonoma de Madrid, Spain — [2]CEA/University of Grenoble Alps, France — [3]Tohoku University, Japan

Ferromagnetic superconductors can show equal spin pairing superconductivity, in form, for example, of a p-wave pair wave function. Among the different candidates, the U-based single crystalline systems stand out because of the real coexistence between the superconducting and ferromagnetic order, and their numerous interesting properties, such as the unusual upper critical field and the field-induced re-entrant superconductivity. Recent measurements show that superconductive pairing is remarkably sensitive to the external magnetic field. However, it is unknown if the magnetic field induces strong difference in the pairing interaction in different parts of the phase diagram. Here we address this issue by a combined study of thermal and electrical transport in UCoGe, under magnetic field up to 15T. We observe that the resistive transition width considerably sharpens in the high field region. In addition, it lies at a lower temperature than the bulk transition observed in the thermal conductance. This shows strongly enhanced vortex mobility in this high field region, in which a freezing transition from a vortex liquid to a glass-like or solid lattice might occur. Meanwhile a sudden change in thermal conductivity is observed inside the superconducting phase. Altogether these results suggest a field-induced change in the superconducting phase. *supported by ERC Pnicteyes

MA 12.10 Mon 17:30 HFT-FT 101

Domain formation in the type-II/1 superconductor niobium — •Alexander Backs[1,2], Tommy Reimann[1,2], Michael Schulz[1,2], Vitaliy Pipich[1,3], Sebastian Mühlbauer[1], and Peter Böni[2] — [1]Heinz Maier-Leibnitz Zentrum, Garching, Germany — [2]Physik-Department E21, Technische Universität München, Garching, Germany — [3]Jülich Center for Neutron Research, Jülich, Germany

In type-II/1 superconductors, an attractive interaction between single magnetic vortices leads to the formation of a magnetic domain structure, denoted intermediate mixed state (IMS). The IMS is made up of flux free domains and regions containing a vortex lattice (VL) [1].

We have studied the nucleation and morphology of the IMS in the type-II/1 s-wave superconductor niobium [1] [2] with a combination of small and ultra small angle neutron scattering and neutron grating interferometry to gain information about the VL, the IMS domains and their spatial distribution, respectively. In the case of strong pinning, the magnetic structure changes from a homogeneous VL into clustered domains upon field cooling. This phase separation sets in below the freezing transition of the VL, thereby demonstrating how vortex pinning can be overcome on a local scale while macroscopically retaining it. The IMS scattering function shows strong similarities to the model of spinodal decomposition where the usual time dependence is implicit in the cooling process.

[1] E. H. Brandt and M. P. Das, Journal of Superconductivity and Novel Magnetism 24, 57 (2011)
[2] T. Reimann et al., Nat. Commun.6, 8813 (2015)
[3] T. Reimann et al., Phys. Rev. B 96, 144506 (2017)

MA 13: Focus Session: Magnetism in Materials Science: Thermodynamics, Kinetics and Defects II (joint session MM/MA)

Sessions: Magnetism III and Magnetism IV

Time: Monday 15:45–18:45 Location: TC 010

Topical Talk MA 13.1 Mon 15:45 TC 010

Ferromagnetic Nuclear Resonance for studying defects in multilayers and nanocomposites : Structure and magnetic properties — •Christian Mény — IPCMS, 23 rue du loess 67034, Strasbourg, France

Nuclear Magnetic Resonance in Ferromagnets (also called Ferromagnetic Nuclear Resonance, FNR) is a rather unknown technique. However it can give very unique information in the study of defects in ferromagnetic films, multilayers, and nanocomposites. The yield of FNR experiments is twofold. On one hand the FNR spectrum reflects the distribution of hyperfine fields in the sample and thus gives information about the different chemical configurations and site symmetries in the sample,their structure and their defects (stacking faults, impurities, grain boundaries...). On the other hand the evolution of the spectral shape against the FNR radio frequency field strength probes the magnetic stiffness of the electronic moments around the nucleus site thus providing information comparable to that given by ferromagnetic resonance measurements. Therefore, combining both yields makes it possible to correlate the inhomogeneous magnetic properties of a sample to its different structural components and defects. A general presentation of FNR will be given in the first part of the presentation; the second part will be focused on the study of defects in nanostructures.

Reference: Y.F. Liu, , C. Meny; Sampling the structure and chemical order in assemblies of ferromagnetic nanoparticles by Nuclear Magnetic Resonance. Nat. Commun.7, 11532 (2016); and references therein.

MA 13.2 Mon 16:15 TC 010

First-principles study of interface energies in Fe-Al superalloy nanocomposites — •Ivana Miháliková[1,2], Anton Slávik[1,2], Martin Friák[1,2], David Holec[3], Nikola Koutná[1,2,4], Monika Všianská[1,5,6], and Mojmír Šob[5,1,6] — [1]Institute of Physics of Materials, Academy of Sciences of the Czech Republic, Brno, Czech Republic — [2]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Brno, Czech Republic — [3]Department of Physical Metallurgy and Materials Testing, Montanuniversität Leoben, Leoben, Austria — [4]Institute of Materials Science and Technology, TU Wien, Vienna, Austria — [5]Central European Institute of Technology, CEITEC MU, Masaryk University, Brno, Czech Republic — [6]Department of Chemistry, Faculty of Science, Masaryk University, Brno, Czech Republic

Fe-Al nanocomposites with a superalloy-type of microstructure possess a great potential as an alternative to the currently used steel grades in high temperature applications. We employ *ab initio* calculations to analyze relations between ordering tendencies of Al atoms in the disordered Fe-18.75at.%Al phase on one hand and thermodynamic, structural and magnetic properties of Fe-Al-based nanocomposites on the other. The Fe-18.75at.%A supercells without 1^{st} and 2^{nd} nearest neighbor Al-Al pairs have a lower energy than those mimicking an ideal disorder (a special quasi-random structure, SQS). The same thermodynamic preference is found also in the case of coherent interfaces with {001}, {011} and {111} crystallographic orientations between Fe_3Al compound and Fe-Al phases with different atomic distributions.

MA 13.3 Mon 16:30 TC 010

***Ab initio* study of magnetic states in superalloy nanocomposite phase Fe_2AlTi** — •Anton Slávik[1,2], Ivana Miháliková[1,2], Martin Friák[1,2], David Holec[3], Monika Všianská[1,4,5], and Mojmír Šob[4,1,5] — [1]Institute of Physics of Materials, Academy of Sciences of the Czech Republic, Brno, Czech Republic — [2]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Brno, Czech Republic — [3]Department of Physical Metallurgy and Materials Testing, Montanuniversitaet Leoben, Leoben, Austria — [4]Central European Institute of Technology, CEITEC MU, Masaryk University, Brno, Czech Republic — [5]Department of Chemistry, Faculty of Science, Masaryk University, Brno, Czech Republic

The Fe_2AlTi intermetallic compound is one of Heusler $L2_1$-structure materials possessing interesting magnetic properties. We study thermodynamic, electronic, structural and elastic properties of different magnetic states in Fe_2AlTi by *ab initio* fixed-spin-moment calculations. A spin-polarized ferrimagnetic state with the magnetic moment of 0.925 μ_B per formula unit is found to be a stable energy minimum at T=0 K. Interestingly, a non-magnetic state has its total energy only by 10.6 meV/atom higher and, consequently, the lowest energy state is found very sensitive to different perturbations. We discuss this weak stability in the case of fairly high statistical probability of occurrence of the non-magnetic state, trigonal strains (to which Fe_2AlTi has a compression-tension asymmetric response), off-stoichiometry and point defects as well as interfaces within Fe-Al-Ti superalloy nanocomposites.

MA 13.4 Mon 16:45 TC 010

Energetics of non-stoichiometric stacking faults in Fe-Nb alloys: An ab initio study — •Ali Zendegani[1], Michaela Šlapáková Poková[2], Christian Liebscher[2], Frank Stein[2], Alvin Noe Collado Ladines[3], Thomas Hammerschmidt[3], Ralf Drautz[3], Fritz Körmann[1], Tilmann Hickel[1], and Jörg Neugebauer[1] — [1]Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf, Germany — [2]Charles University, Prague, Czech Republic — [3]ICAMS, Ruhr-Universität Bochum, Bochum, Germany

The microstructure in structural materials plays an essential role for their mechanical properties. In Fe-Nb alloys a hardening via TCP phases (e.g. Laves Fe2Nb and Fe7Nb6) can be achieved. At the same time, various types of stacking faults occur during deformation. In the present work, we investigate the correlation of both features in the C14 Fe2Nb Laves phase. For this purpose, density functional theory calculations are combined with thermodynamics concepts. Particular care has been taken to take atomic relaxation effects and magnetic degrees of freedom into account. We proof that excess Nb will segregate to these planar defects and result in a local phase transformation next to it. The energetics of these structures are compared to the phase separation as predicted by the bulk phase diagram. Comparing our results with high-quality TEM measurements has revealed that some of the complex crystal structures next to basal and pyramidal stacking faults are in a constrained state.

30 min. break

Topical Talk MA 13.5 Mon 17:30 TC 010

Improving the finite-temperature description of magnetic materials — •Anders Bergman — Department of Physics and Astronomy, Uppsala University,Uppsala, Sweden

State-of-the-art simulations based on electronic structure theory and atomistic models have now evolved to a point where computer-guided materials design has become a realistic option for many classes of materials. In this talk we will introduce improvements to the standard description of finite-temperature magnetism with the aim of increasing the predictive capability of these simulations further.

We present an extended atomistic spin model obtained by augmenting the Heisenberg Hamiltonian to take longitudinal fluctuations of the magnetic moments into account. This is done by parametrisation from a first-principles basis, interpolating from low-temperature ferromagnetic and high-temperature paramagnetic reference states. The method gives a good agreement of Curie temperatures and paramagnetic properties compared with experiments as well as similar, earlier theoretical models.

Introducing quantum statistics into atomistic simulations has been shown to improve the observed temperature dependence of the magnetisation and of the magnetic specific heat. This allows for a more realistic modelling of the magnetic contribution to the free energy and thus a better description of phase-stabilities and related properties. We present how the quantum statistics can be modelled with varying levels on complexity and demonstrate the method for both elemental systems and magnetic alloys.

MA 13.6 Mon 18:00 TC 010

Interplay between magnetic and energetic properties in FeMn alloys from first principles — •Anton Schneider[1], Chu Chun Fu[1], Cyrille Barreteau[2], and Frédéric Soisson[1] — [1]CEA, DEN, Service de Recherches de Métallurgie Physique, F-91191 Gif-sur-Yvette, France — [2]CEA, DRF, Service de Physique de l'Etat Condensé, F-91191 Gif-sur-Yvette, France

Iron-based alloys play a central role in several technological applications. In these alloys, the magnetism has an important impact on thermodynamic and kinetic behaviors, and on the properties of point defects. Especially, iron-based alloys may exhibit complex magnetic structures if the magnetic ordering tendency of the alloying element in its pure phase differs from that of iron.

Iron-Manganese bcc alloys are studied using Density Functional Theory (DFT) in order to elucidate the correlation between the magnetic structures, and the energetics of Mn atoms and clusters in the presence of vacancies and interstitial impurities. The FeMn alloys exhibit well distinct magnetic interactions between the Fe atoms and the Mn solutes depending on local chemical environments, which are rationalized in terms of electronic structures. Both low-energy magnetic collinear and non-collinear states are investigated.

The DFT results are then used to parameterize new Heisenberg-like models, in the presence of vacancies, aiming at investigating the finite-temperature magnetic effects employing Monte Carlo simulations. A particular attention is given to the role of magnetic short-range order on the vacancy formation energy, as a function of temperature.

MA 13.7 Mon 18:15 TC 010

Machine Learning assisted Heisenberg model for systems with ill-defined pairwise magnetic interactions — •Osamu Waseda, Omkar Hegde, and Tilmann Hickel — MPIE

Magnetic interactions are important for the stability of structural phases as well as for various thermophysical effects such as magnetocalorics. In order to determine their free energy contribution in Fe-based materials, the Heisenberg model has been used as a handy method for decades. Despite its simplicity, there is little experience with the application of this model to systems containing various types of atoms and/or structural defects, as their interaction parameters cannot be defined straightforwardly. In this study, data sets for Fe-Mn systems containing structural defects are created from spin-polarized DFT calculations. They are then translated into the Heisenberg parameters via Ridge regression. Finally, the contribution of the magnetic interactions to the specific heat is determined through Monte Carlo simulations.

MA 13.8 Mon 18:30 TC 010

Numerical simulation of spin fluctuations in materials science: magnetic bond-order potentials and hybrid Monte Carlo — •Ning Wang, Thomas Hammerschmidt, and Ralf Drautz — ICAMS, Ruhr-Universität Bochum, Bochum, Germany

The finite-temperature properties of many magnetic materials are to a large degree influenced by spin fluctuations. The numerical simulation of these effects, however, faces several obstacles. In particular, the modelling of the magnetic interactions at the quantum-mechanical level should be neither oversimplified nor too computationally expensive. Furthermore, an efficient numerical sampler is required in order to treat the high-dimensional integration problem of the thermal expectation values. Our modelling approach are analytic bond-order potentials based on tight-binding. To treat the sampling problem, we extended the hybrid Monte Carlo sampler so that it will also work for the classical spin system. We furthermore developed an auxiliary-Hamiltonian method in order to improve the sampling efficiency. With this methodology, we simulate the magnetic phase transitions in BCC iron and determine the magnetic free energy difference between the BCC and FCC states of iron.

MA 14: INNOMAG e.V. Dissertationspreis 2018 / Ph.D. Thesis Prize

Die Arbeitsgemeinschaft Magnetismus der DPG hat einen Dissertationspreis ausgeschrieben, welcher auf der Frühjahrstagung der DPG im März 2018 in Berlin vergeben wird. Ziel des Preises ist die Anerkennung herausragender Forschung im Rahmen einer Promotion und deren exzellente Vermittlung in Wort und Schrift. Im Rahmen dieser Sitzung tragen die vier besten der für ihre an einer deutschen Hochschule durchgeführten Dissertation Nominierten vor. Im direkten Anschluss entscheidet das Preiskommittee über den Gewinner bzw. die Gewinnerin des INNOMAG e.V. Disserationspreises 2018 in Höhe von 1000 EURO.

Talks will be given in English!

Time: Monday 15:00–16:55 Location: H 0112

Invited Talk MA 14.1 Mon 15:00 H 0112

On the magnetocaloric properties of Heusler compounds — •Tino Gottschall — TU Darmstadt, Institute of Material Science, Germany

Large magnetocaloric effects can be obtained in the Heusler alloys Ni-Mn-In and Ni-Mn-In-Co during the magnetostructural phase transformation between the low-temperature paramagnetic martensite and the high-temperature ferromagnetic austenite phase. The martensitic transition is furthermore sensitive to a magnetic field but also to hydrostatic pressure. It can therefore be induced by those external stimuli [1]. However, the existence of thermal hysteresis in those materials limits the reversible adiabatic temperature and isothermal entropy change. The magnetocaloric effect under cycling can be enhanced in so-called minor loops of hysteresis [2]. On the contrary, in very high magnetic-field rates as well as in micrometer-sized single particles, the thermal hysteresis increases significantly [3]. In order to understand the contrasting behavior of small fragments compared to bulk, a finite element model is introduced, from which the importance of mechanical stress during the transition becomes apparent [4].

[1] T. Gottschall et al., Phys. Rev. B 93, 184431 (2016).
[2] T. Gottschall et al., Appl. Phys. Lett. 106, 021901 (2015).
[3] T. Gottschall et al., Phys. Rev. Applied 5, 024013 (2016).
[4] T. Gottschall et al., Adv. Funct. Mater. 27, 1606735 (2017).

Invited Talk MA 14.2 Mon 15:25 H 0112

Topological Magnon Materials and Transverse Magnon Transport — •Alexander Mook — Institut für Physik, Martin-Luther-Universität, D-06120 Halle, Germany

Since Joule heating limits the efficiency of today's spintronics devices, electrons as carriers of information may be replaced by magnons, requiring a detailed understanding of magnon transport properties. Particularly fascinating magnon transport properties are found in topological magnon insulators that exhibit a thermal magnon Hall effect [1], calling for a general analysis of topological magnon materials like, for example, magnon Weyl semimetals [2] and magnon nodal-line semimetals [3]. I demonstrate how such topological magnon matter and its magnon Hall effects can be understood within linear spin-wave theory and Berry-phase theory. Moreover, I present a new method for the calculation of magnon transport based on atomistic spin dynamics simulations and the Green-Kubo relations. It is used to study the transverse magnon transport in the topological magnon insulator Cu(1,3-benzenedicarboxylate) [4] and in a skyrmion crystal [5].

[1] H. Katsura et al., Phys. Rev. Lett. 104, 066403 (2010); Y. Onose et al., Science 329, 297 (2010); R. Matsumoto et al., Phys. Rev. Lett. 106, 197202 (2011); A. Mook et al., Phys. Rev. B 89, 134409 (2014) [2] F.-Y. Li et al., Nature Commun. 7, 12691 (2016); A. Mook et al., Phys. Rev. Lett. 177, 157204 (2016) [3] A. Mook et al., Phys. Rev. B 95, 014418 (2017) [4] Hirschberger et al., Phys. Rev. Lett. 115, 106603 (2015); A. Mook et al., Phys. Rev. B 94, 174444 (2016) [5] A. Mook et al., Phys. Rev. B 95, 020401(R) (2017)

Invited Talk MA 14.3 Mon 15:50 H 0112

Ferromagnet-Free Magnetoelectric Thin Film Elements — •Tobias Kosub — Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, Dresden, Germany

Thin film spintronic elements could complement conventional electronic computing in the future in applications such as high efficiency data processing. Magnetoelectric antiferromagnets are attractive for two reasons: First, they allow electric field actuation of magnetic state changes. This is more energy efficient than charge current based manipulation because the latter is accompanied by conduction losses. Second, antiferromagnets offer intrinsic robustness against magnetic stray fields and potentially picosecond addressability.

This thesis encompasses the design, development, realization and testing of novel magnetoelectric thin film elements that do not rely on ferromagnets, but are based entirely on magnetoelectric antiferromagnets such as Cr_2O_3 [1]. Using a new electrical measurement scheme [2], a purely antiferromagnetic memory prototype is demonstrated, which greatly exceeds the performance of conventional counterparts based on ferromagnets.

[1] T. Kosub et al., *Nature Commun.* **8**, 13985 (2017).
[2] T. Kosub et al., *Phys. Rev. Lett.* **115**, 097201 (2015).

Invited Talk MA 14.4 Mon 16:15 H 0112

Optically induced ferro- and antiferromagnetic dynamics in the rare-earth metal dysprosium — •Nele Thielemann-Kühn — Helmholtz-Zentrum Berlin, Albert-Einstein-Str. 15, 12489 Berlin, Germany — Freie Universität Berlin, Fachbereich Physik, Arnimallee 14, 14195 Berlin, Germany

By comparing ferro- and antiferromagnetic dynamics in one and the same material -metallic dysprosium- we show both to behave fundamentally different. Antiferromagnetic order is considerably faster and much more efficiently manipulated by optical excitation than its ferromagnetic counterpart. Within a depth-resolved study of optically induced antiferromagnetic dynamics we find the magnetic order to be suppressed by a long-ranging process. We assign this fast and extremely efficient mechanism to an interatomic transfer of angular momentum within the spin-system via fast diffusion of excited valence electrons. On longer picosecond-timescales the antiferromagnetic order is further reduced only in regions where the laser directly excited the sample. In addition we observe two clearly distinguishable regions with different magnetic properties within the sample hinting to a long-living non-equilibrium state of the 4f-magnetic system. The complex depth dependent quenching behavior of the antiferromagnetic order is indicative for the interplay of different delocalized as well as local spin-scattering channels.

Selection and announcement of the winner.

MA 15: INNOMAG e.V. Diploma-/Master Prize 2018

Die Arbeitsgemeinschaft Magnetismus der DPG hat einen Diplom-/Masterpreis ausgeschrieben, welcher auf der Frühjahrstagung der DPG im März 2018 in Berlin vergeben wird. Ziel des Preises ist die Anerkennung herausragender Forschung im Rahmen einer Diplom-/Masterarbeit und deren exzellente Vermittlung in Wort und Schrift. Im Rahmen dieser Sitzung tragen die drei besten der für ihre an einer deutschen Hochschule durchgeführten Diplom-/Masterarbeit Nominierten vor. Im direkten Anschluss entscheidet das Preiskommittee über den Gewinner bzw. die Gewinnerin des INNOMAG e.V. Diplom/Master-Preises 2018 in Höhe von 500 EURO.
Talks will be given in English!

Time: Monday 16:55–18:05 Location: H 0112

Invited Talk MA 15.1 Mon 16:55 H 0112

Magnetic particle mapping with magnetoelectric sensors for characterization of bioscaffolds — •Ron-Marco Friedrich[1], Sebastian Zabel[1], Jan-Martin Wagner[1], Christine Selhuber-Unkel[2], and Franz Faupel[1] — [1]CAU Kiel, Institute for Material Science, Chair for Multicomponent Materials, Kaiserstr. 2, 24143 Kiel, Germany — [2]CAU Kiel, Institute for Material Science - Biocompatible Nanomaterials, Kaiserstr. 2, 24143 Kiel, Germany

Bioscaffolds for cell growth have great potential in the area of medical life science. The characterization of the scaffolds with regard to the cell growth needs to meet certain objectives to ensure non-invasiveness and non-destructiveness. Here, a novel detection method for magnetically labeled cells using magnetoelectric (ME) sensors is introduced where, similar to magnetic particle imaging (MPI), the nonlinear magnetization behavior of magnetic particle ensembles is used to detect higher harmonic excitations. The ME sensor consists of a piezoelectric and magnetostrictive thin film on a freestanding cantilever, which shows a sharp mechanical resonance and anisotropy in its sensitivity. This leads to a selective signal acquisition with respect to the spatial orientation of the sensor and the applied excitation frequency. Thus, by moving the sensor over a sample, we can locally detect higher harmonic excitations and create a map of the magnetic field of the magnetic particles. We describe the abilities of the detection system and create a forward simulation of this kind of imaging system to reconstruct the particle distribution.

Invited Talk MA 15.2 Mon 17:15 H 0112

Uncovering Chiral and Topological Orbital Magnetism of Domain Walls and Skyrmions
— •Fabian R. Lux —
Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

In the field of spin-orbitronics, the orbital physics of electrons plays a central role, and the orbital magnetization represents a key concept for its controlled detection and manipulation. While the orbital magnetism of collinear ferromagnets is relatively well understood, much less is known about it for non-collinear structures such as magnetic skyrmions and domain walls. By employing a semiclassical Green's function formalism, we demonstrate how the orbital magnetization in these extended chiral magnetic systems can be understood as the electronic response to emergent electromagnetic fields [1]. We discovered that in such systems the spin-orbit interaction can be used to a great advantage in that it promotes a complex interplay of real-space and k-space topology leading to enhanced orbital responses in interfacial chiral magnets. Besides discussing possible applications of the emergent orbital magnetism in chiral spin systems we also suggest new perspectives for the field of chiral orbitronics.

[1] F. R. Lux *et al.*, arXiv:1706.06068 (2017)

Invited Talk MA 15.3 Mon 17:35 H 0112

Unified description of high frequency magnetodynamics, and a new way of measuring the magnon contribution to the specific heat. — •Benjamin Zingsem[1,2], Michael Winklhofer[3], Sabrina Masur[4], Paul Wendtland[1], Ruslan Salikov[1], Florian M. Römer[1], Ralf Meckenstock[1], and Michael Farle[1] — [1]University Duisburg-Essen, 47057 Duisburg, Germany — [2]ERC und PGI, Fz Jülich GmbH, 52425 Jülich, Germany — [3]University of Oldenburg, 26129 Oldenburg, Germany — [4]University of Cambridge, Cambridge CB3 0HE, UK

We present a general analytic solution of the ferromagnetic high frequency susceptibility tensor, as well as a new method of measuring the magnon contribution to the heat capacity in ferromagnetic systems, predicted by this solution. This linearized function can be directly applied to ferromagnetic systems with any magnetic energy landscape, any static applied fields and any sufficiently small dynamic fields. It unifies a multitude of approaches know throughout literature and naturally describes the entire reciprocal space for magnons in one simple function. In addition, this approach predicts a new type of metastable eigenmode which can be excited in conventional ferromagnetic resonance experiments, by sweeping the field in an unconventional way. These predicted modes where measured and the deduced behavior of the heat capacity is presented. Furthermore, by including the chiral Dzyaloshinskii-Moriya interaction, this formalism yields a possibility to determine the chiral energy density for small chiral coupling, which was previously inaccessible.

Selection and announcement of the winner.

MA 16: Magnetic characterization techniques

Time: Tuesday 9:30–12:15 Location: H 0112

MA 16.1 Tue 9:30 H 0112

Nanoscale magneto-optical imaging using a compact extreme-UV source based on high-harmonic generation — •Sergey Zayko[1], Ofer Kfir[1,2], Michael Heigl[3], Christina Nolte[1], Murat Sivis[1], Marcel Möller[1], Birgit Hebler[3], Sri Sai Phani Kanth Arekapudi[3], Daniel Steil[1], Sascha Schäfer[1], Oren Cohen[2], Stefan Mathias[1], Manfred Albrecht[3], and Claus Ropers[1] — [1]University of Göttingen, Germany — [2]Physics Department, Technion, Israel Institute of Technology, Israel — [3]Institute of Physics, University of Augsburg, Germany

Magnetic topological excitations such as domain walls or skyrmions are of great importance for fundamental research and applied science [1,2]. High-harmonic generation offers an exciting possibility to study such physical phenomena at their characteristic nanometre spatial and femtosecond temporal scales using a compact experimental setup [3]. Here, we demonstrate the first results on magnetic imaging with high-harmonic radiation. By using circularly polarized harmonics [4], we access XMCD contrast from nanoscale magnetic domains and obtain quantitative, diffraction-limited absorption and phase images with sub-50 nm spatial resolution. These results open the way towards comprehensive magneto-optical studies with unprecedented spatio-temporal resolution on a table top.

[1] Allwood et al., Science 309, Issue 5741, pp. 1688-1692. (2005)
[2] Mühlbauer et al., Science 323, Issue 5916, pp. 915-919 (2011)
[3] Kfir, Zayko et al., in press.
[4] Fleischer et al.,Nat. Photonics 8, 543-549 (2014)

MA 16.2 Tue 9:45 H 0112

Electron microscopy: magnetic properties in another kind of light — •Daniela Ramermann, Inga Ennen, and Andreas Hütten — Faculty of Physics, University of Bielefeld, Universitätsstraße 25, 33615 Bielefeld, Germany

Modern methods in Transmission Electron Microscopy give deeper insights not only into the structural characterisation but also into magnetic properties of materials. In this talk we want to show the possibilites of Lorentz microscopy, differential phase contrast imaging and EMCD measurements for determining the magnetic properties of cobalt and magnetite nanoparticles and Heusler thin film systems.

MA 16.3 Tue 10:00 H 0112

EMCD measurements with electron vortex beams on ferrimagnetic — •Darius Pohl[1], Sebastian Schneider[1], Jan Rusz[2], Jakob Spiegelberg[2], Peter Tiemeijer[3], Sorin Lazar[3], Xiaoyang Zhong[4], Victor Brabers[5], Kornelius Nielsch[1], and Bernd Rellinghaus[1] — [1]IFW Dresden — [2]U Uppsala — [3]Thermo Fisher Scientific — [4]NCEM Beijing — [5]U Eindhoven

Electron vortex beams (EVBs) carry a discrete orbital angular momentum (OAM), L, and are predicted to reveal electron energy loss magnetic chiral dichroism (EMCD) upon interacting with magnetic samples down to the atomic scale. Our optical setup allows for scanning TEM investigations (STEM) with vortex beams, whose OAM is selected by means of an additional discriminator aperture [1]. As a proof of principle experiment, two samples have been chosen, Sr_2FeMoO_6 and $BaFe_{11}TiO_{19}$. For both samples, an EMCD signal is found by principle component and vector component analysis (PCA and VCA) in the acquired spectra. However, local analysis still suffer from a low signal-to-noise ratio. The status quo of the experiments and simulations of the interaction of the EVB with the ferrimagnetic samples will be presented.

[1] D. Pohl, S. Schneider, P. Zeiger, J. Rusz, P. Tiemeijer, S. Lazar, K. Nielsch, B. Rellinghaus, Sci. Rep. 7 (2017) 934.

MA 16.4 Tue 10:15 H 0112

Detection of ferromagnetic resonance with a proximate organic light emitting diode — •Tobias Grünbaum, Sebastian Bange, Christian H. Back, and John M. Lupton — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstraße 31, 93053 Regensburg, Germany

Several investigations in the newly emerging field of organic spintronics are based on structures of an organic semiconductor in combination with an adjacent ferromagnet. Prominent examples are spin pumping into an organic semiconductor [1] and organic spin valves [2].

We investigated the influence of a magnetic YIG film undergoing ferromagnetic resonance on an organic light emitting diode. Due to a bolometric effect and subsequent heat conduction from the YIG to the organic light emitting diode, the ferromagnetic resonance spectrum of the YIG is reproduced in the voltage drop across the diode. This includes the lineshape, the characteristic frequency dependence of the resonance field, as well as signatures of nonlinear phenomena. Our results show that a bolometric heating effect is the dominant influence of the ferromagnetic resonance on an organic light emitting diode at high excitation power.

[1]: Sun D., et al. Nat. Mater. 15, 863-869 (2016)
[2]: Ehrenfreund E. & Vardeny Z. V., Phys. Chem. Chem. Phys. 15, 7967-7975 (2013)

MA 16.5 Tue 10:30 H 0112

Gold and Graphene Hall Sensors for Scanning Magnetic Field Measurements on Magnetic Microstructures — •Manuela Gerken, André Müller, Davood Momeni Pakdehi, Thomas Weimann, Sibylle Sievers, and Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

Within the overall miniaturization, also magnetic devices are being scaled down into the micro- and nanometer range. This leads to an increasing demand for high resolution quantitative metrology for the resulting spatially varying device stray fields. One promising approach is scanning magnetic field microscopy with Hall sensors. Here, we will present our results on the development of gold and graphene Hall sensors with active areas down to 50 nm x 50 nm. There are some hints that these materials are superior to semiconductor sensors for small active areas and at room temperature (RT). For example, gold sensors are supposed to have a better signal to noise ratio due to the higher applicable current. In contrast, graphene can reveal low carrier density and thus a high RT Hall coefficient. We will address fabrication and design issues of both types of nano-Hall sensors. Furthermore we will discuss the results of the sensor characterization including sensor sensitivity, stability and noise figures as well as an estimation of the uncertainty budget for quantitative magnetic field measurements.

15 minutes break

MA 16.6 Tue 11:00 H 0112

Uniaxial neutron polarization analysis of bulk ferromagnets — •Dirk Honecker — Institut Laue-Langevin, Grenoble, France

Polarized neutron scattering is a powerful technique for investigating the structure and dynamics of condensed matter, in particular magnetic materials and superconductors.

In this contribution, a description of the polarization of scattered neutron of bulk magnetic material will be presented. With respect to small-angle neutron scattering, the model takes into account the relative strength between nuclear and magnetic scattering amplitude as well as interparticle correlations arising from the local magnetic environment in densely packed particle systems.

MA 16.7 Tue 11:15 H 0112

Neutron Depolarization Microscope for Imaging of Ferromagnetic Phase Transitions: Ni_3Al and $HgCr_2Se_4$ under pressure — •Pau Jorba[1], Michael Schulz[2], Daniel Hussey[3], Boris Khaykovich[4], Muhuammad Abir[4], Marc Seifert[1], Vladimir Tsurkan[5], Allois Loidl[5], and Christian Pfleiderer[1] — [1]Physik-Department, Technische Universität München, Germany — [2]Heinz-

Maier-Leibnitz Zentrum (MLZ), TUM, Germany — [3]NIST, Gaithersburg, MD, USA — [4]Nuclear Reactor Laboratory, Massachusetts Institute of Technology, USA — [5]Center for Electronic Correlations and Magnetism, University of Augsburg, Germany

We performed neutron depolarization imaging of a large Ni_3Al crystal, and a small $HgCr_2Se_4$ spinel under pressure, to probe bulk magnetic inhomogeneities in the ferromagnetic transition temperature with the spatial resolution about 100 μm. To obtain these spatially resolved depolarization images we employed a neutron microscope equipped with Wolter optic, a neutron image-forming lens, as well as a focusing neutron guide. The depolarization images on Ni_3Al clearly show that the sample doesn't homogeneously go through the ferromagnetic transition. The results on the chromium spinel highlight the advantage of this technique especially for small samples, or sample environments with restricted sample space, as we are able to significantly improve the resolution while decreasing the acquisition time. The novel optical design that enabled acquisition of the high spatial resolution neutron depolarization images is described in detail and image results are compared to a conventional radiography setup without a lens.

MA 16.8 Tue 11:30 H 0112

Magneto-Structural Study of Dihalo-Bridged Copper Dimers: Intra- and Interdimer Interactions as Revealed by Single-Crystal ESR Spectroscopy — •Dijana Žilić[1], Debdeep Maity[1], Mario Cetina[2], Krešimir Molčanov[1], Zoran Džolić[1], and Mirta Herak[3] — [1]R. Bošković Institute, Zagreb, Croatia — [2]Faculty of Textile Technology, Zagreb, Croatia — [3]Institute of Physics, Zagreb, Croatia

Four complexes with two different oxalamide ligands were synthesized: [CuLA(μ-X)]2 and [CuLV(μ-X)]2, X=Cl or Br. The geometry at each Cu(II) ion is ideal or near ideal square pyramidal, whereas two pyramids share one base-to-apex edge with parallel basal planes. The complexes are linked by hydrogen bonds into infinite chains and are further linked into a 3D network. Magn. susc. measurements show that coppers in the dimers are weakly AFM coupled.

Despite very similar structures of these complexes compared with the complexes previously reported and characterized by similar X-ray, magnetization and powder ESR results, single crystal ESR spectra reveal significant differences. Here presented complexes show unusual anisotropic splitting and merging of ESR lines when their crystals rotate in magn. field. The observation of this partially resolved intradimer dipolar splitting enabled estimation of weak interdimer exchange interaction parameter.[1,2]

[1] Žilić D. et al., Dalton Trans. 2014, 43, 11877.
[2] Žilić D. et al., ChemPhysChem 2017, 18, 2397.

Supported by Croatian Science Foundation HrZZ-UIP-2014-09-9775.

MA 16.9 Tue 11:45 H 0112

Mechanical detection of nanomagnetic phenomena employing coupled nano- and micro-cantilever systems — •Thomas Mühl, Christopher Friedrich Reiche, Julia Körner, and Bernd Büchner — IFW Dresden, Dresden, Germany

Magnetic force microscopy (MFM) and cantilever magnetometry are nanomagnetic measuring techniques that rely on cantilever-based force transducers. Their sensitivity can be improved by reducing the cantilever's dimensions which may lead to difficulties in their read-out. Our recently developed sensor concept [1,2] addresses this issue by a co-resonant coupling of a tiny nanocantilever to a rather conventional microcantilever. The co-resonance is achieved through matching of the eigenfrequencies of the two cantilevers. Thus, if the highly sensitive nanocantilever is subject to an external interaction, the oscillatory state of the coupled system as a whole is changed. This change can be detected at the microcantilever with standard equipment. We present analytical approximations of the resonant behavior, amplitude relations, and effective quantities with respect to damping, mass, and spring constant of the coupled system. Furthermore, we show how the experimental implementation of our approach in MFM enables a huge sensitivity enhancement in case of an in-plane sensitivity imaging mode with the nanocantilever arranged in a pendulum-type geometry.

[1] C. F. Reiche, J. Körner, B. Büchner, and T. Mühl, Nanotechnology 26, 335501 (2015).
[2] J. Körner, C. F. Reiche, R. Ghunaim, R. Fuge, S. Hampel, B. Büchner, and T. Mühl, Sci. Rep. 7, 8881 (2017).

MA 16.10 Tue 12:00 H 0112

Magnetic resonance force microscopy for condensed matter — •Gesa Welker, Martin de Wit, Jelmer Wagenaar, Marc de Voogd, Arthur den Haan, Tom van der Reep, Lucia Bossoni, and Tjerk Oosterkamp — Leiden Institute of Physics, Leiden, The Netherlands

Magnetic resonance force microscopy (MRFM) allows investigation of various kinds of spin-related material properties in small sample volumes. We reduced the operating temperature of this technique by 2 orders of magnitude to 10 mK. As a demonstration, we measured the nuclear spin-lattice relaxation time on copper at temperatures down to 42 mK, verified by the Korringa relation [1] with an interaction volume of $(30\text{nm})^3$. Furthermore, we have conducted a study of the dissipation and frequency shifts of a cantilever interacting with all surrounding spins, allowing us to measure the density and relaxation time of dangling bonds on a SiO_2 surface [2] and impurity spins in bulk diamond. This enables us to understand some problems involving 2LS, one of the bottlenecks in the development of optomechanical-like hybrid quantum devices. Finally, we have developed an innovative method for using the higher modes of the cantilever as radio-frequency (rf) source, removing the need for an on-chip rf source [3]. This is an important step towards an MRFM which can be widely used in condensed matter physics, e.g. to investigate inhomogeneous electron systems.

[1] Wagenaar et al. Phys. Rev. Appl. 6, 014007 (2016). [2] de Voogd et al. Sci. Rep. 7, 42239 (2017). [3] Wagenaar et al. Phys. Rev. Appl. 7, 024019 (2017).

MA 17: PhD Symposium: Ultrafast spin-lattice interactions (joint session MA/AKjDPG)

The immensely fascinating field of magnetism research has branched into many lively communities such as spintronics, ultrafast demagnetization, all-optical switching, multiferroic materials, domain walls, magnetic textures and spin caloritronics just to mention a few. All of these hot research topics share that the relevant interacting magnetic moments are arranged within the framework of an atomic lattice which itself interacts with the spin system. The lattice thus does not only influence the geometrical arrangement of the magnetic moments but also serves as a major bath for energy, entropy and most importantly also angular momentum transfer within the studied systems. The symposium aims at exchanging ideas and at fostering the discussion about the effects of the spin- lattice interaction among various areas of magnetism research. We highly welcome contributions that explain basic mechanisms and results of the spin-lattice interaction from all communities. Spin-lattice interaction can be considered as one of the prototypical coupling mechanisms within correlated materials and the condensed matter research in general. It is a very timely topic as many applications in future information technology such as spintronic-devices, heat assisted magnetic recording, implementations of the Spin-Seebeck, all-optical magnetization switching greatly benefit from an understanding of this basic effect.

Organized by: Alexander von Reppert (U. Potsdam), Vivek Unikandanunni, (U. Stockholm), Kumar Neeraj, (U. Stockholm), Neha Jha (U. Greifswald), Tobias Wimmer, (Walther Meißner Institute

München), Kamil Bobowski, (FU Berlin)

Time: Tuesday 9:30–13:15 Location: H 1012

Introduction by the organizers

Invited Talk MA 17.1 Tue 9:35 H 1012
Understanding spin and lattice interactions at ultrafast timescales — •Peter M. Oppeneer — Uppsala University, S-75120 Uppsala, Sweden

The interactions between spin moments and the crystal lattice are, in thermal equilibrium, responsible for a variety of phenomena, such as magnetostriction, magnetoelasticity, spin-reorientation transitions etc. In recent years these fundamental interactions are being probed on ultrafast timescales, which has led to discoveries of unexpected phenomena, as e.g. ultrafast demagnetization, breaking of exchange interactions, spin currents and all-optical switching. A characteristic feature of these discoveries is that an ultrashort excitation initiates highly correlated, out-of-equilibrium interactions of electrons, spins, and ions.

In this overview I survey the current understanding of ultrafast processes involving spins, phonons and hot electrons, aiming to go beyond a purely phenomenological picture and achieve atomistic theory. I shall address electron-phonon spin dissipation in the context of ultrafast laser-induced demagnetization, multiscale modeling of breaking of the exchange interaction, and helicity-induced all-optical switching. A second emerging area concerns ultrafast nonequilibrium energy flow between hot electrons and phonons; recent results emphasize that this flow proceeds in a manner different from the commonly used two-temperature model, and that therefore new theoretical modeling is required to capture the nonequilibrium electron-spin-lattice interplay.

5 minutes break

MA 17.2 Tue 10:25 H 1012
Magnetic and Structural Dynamics in Antiferromagnetically Coupled Fe/Cr Superlattices — •Daniel Schick[1,2], Daniel Bürgler[3], Niko Pontius[2], Stefan Eisebitt[1], and Christian Schüssler-Langeheine[2] — [1]Max-Born-Institut für Nichlineare Optik und Kurzzeitspektroskopie, Max-Born-Str.2a, Berlin, 12489, Germany — [2]Institut für Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Str. 15, Berlin, 12489, Germany — [3]Forschungszentrum Jülich GmbH, Wilhelm-Johnen-Straße 52428 Jülich, Germany

Employing the femtosecond soft X-ray pulses with variable polarization and photon energy delivered by the FemtoSpeX facility at the electron storage ring BESSY II we are able to probe the AFM (resonant magnetic diffraction), FM (XMCD), and structural (non-resonant diffraction) dynamics of Fe/Cr superlattices in one and the same pump-probe experiment. Hence, we can directly compare AFM vs. FM spin dynamics in the same material system by only applying a moderate magnetic field (< 100 mT). Moreover, we can probe the sub-ps structural dynamics due to coherent phonon excitation and its interaction with the spin system. The element selectivity of the resonant X-ray techniques further allows for differentiating the spin dynamics of the initially FM Fe and the non-magnetic Cr layers after photoexcitation and thus for probing possible transient magnetization in Cr due to ultrafast spin injection from the Fe layers.

Invited Talk MA 17.3 Tue 10:40 H 1012
Spin-Lattice coupling in ultrafast magnetization dynamics — •Bert Koopmans — Department of Applied Physics, and Institute for Photonic Integration (IPI),Eindhoven University of Technology, P.O. Box 513, 5600 MB Eindhoven, The Netherlands

Novel schemes for controlling the ferromagnetic state at the femtosecond time scale by pulsed laser excitation have received great current interest recently. Driving systems into the strongly non-equilibrium regime, it has been shown possible not only to fully quench magnetic order, and but even to reverse the magnetic moment by a single pulse.

In this tutorial I will start with a historical review of the field of fs control of the magnetic state by pulsed laser excitation, introduce some of the time-resolved experimental techniques, and discuss the key questions that need to be answered. Next, I will explain the role of spin-lattice coupling in the process of ultrafast loss of magnetic order, including the local dissipation of angular momentum via Elliott-Yafet spin-flip scattering. Also the importance of laser-induced spin currents will be emphasized. Experimental results on a variety of systems and materials will be compared to predictions by the so-called microscopic three-temperature model. The importance of tuning both spin-flip scattering and spin currents for establishing all-optical switching (AOS) of the magnetization will be highlighted. Some of our most recent experiments on AOS by single fs pulses in synthetic ferromagnetic systems will be discussed.

15 minutes break

Invited Talk MA 17.4 Tue 11:25 H 1012
The role of spin-lattice interaction in optical control of magnetism — •Alexey Kimel — Radboud University, Nijmegen, The Netherlands

The action of electric field of light on electronic dipoles, being the largest perturbation in physics of light-matter interaction, conserves the spin of electron. This is why experiments showing the possibility of ultrafast and efficient control of spins with the help of femtosecond laser pulses are among the most heavily debated topics in magnetism. In my talk I will review the progress in understanding of ultrafast laser-induced magnetization dynamics. In particular, I would like to discuss the roles of the spin-lattice interaction in heat-driven, heat-assisted, and heat-free mechanisms of optical control of magnetic order.

MA 17.5 Tue 11:55 H 1012
Structural dynamics during laser-induced ultrafast demagnetization — •Emmanuelle Jal[1], Victor Lopez-Flores[2,3], Niko Pontius[4], Tom Ferte[5], Christine Boeglin[5], Boris Vodungbo[1], Jan Lüning[1,2], and Nicolas Jaouen[2] — [1]Sorbonne Universités, UPMC Univ. Paris 06, CNRS, LCPMR, 75005 Paris, FRANCE — [2]Synchrotron SOLEIL, Saint-Aubin, Boite Postale 48, 91192 Gif-sur-Yvette Cedex, FRANCE — [3]CSIC - University of Seville, Av. Americo Vespucio, 49, 41092 Seville, SPAIN — [4]HZB für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin, GERMANY — [5]Université de Strasbourg, CNRS, IPCMS, UMR 7504, F-67000 Strasbourg, FRANCE

I will present our investigation of the infrared laser-pulse-induced ultrafast demagnetization process in a thin Ni film, which characterizes simultaneously magnetization and structural dynamics [PRB 95 184422]. This is achieved by employing femtosecond timeresolved x-ray resonant magnetic reflectivity (tr-XRMR) as the probe technique. The experimental results reveal unambiguously that the subpicosecond magnetization quenching is accompanied by strong changes in nonmagnetic x-ray reflectivity. These changes vary with reflection angle, and changes up to 30% have been observed. By modeling the x-ray reflectivity of the investigated thin film, we can reproduce these changes by a variation of the apparent Ni layer thickness of up to 1%. Extending these simulations to larger incidence angles, we show that tr-XRMR can be employed to discriminate experimentally between currently discussed models describing the ultrafast demagnetization phenomenon.

5 minutes break

Invited Talk MA 17.6 Tue 12:15 H 1012
Driving magnetization precession by dynamical compressive and shear strain in a low-symmetry metallic film — •Alexandra M. Kalashnikova[1], Tetiana L. Linnik[2], Vladimir N. Kats[1], Jasmin Jaeger[3], Alexey S. Salasyuk[1], Dmitri R. Yakovlev[3], Andrew W. Rushforth[4], Andrey V. Akimov[4], Manfred Bayer[3], and Alexey V. Scherbakov[1,3] — [1]Ioffe Institute, St. Petersburg, Russia — [2]Department of Theoretical Physics, V. E. Lashkaryov Institute of Semiconductor Physics, Kyiv, Ukraine — [3]Experimentelle Physik 2, Technische Universität Dortmund, Dortmund, Germany — [4]School of Physics and Astronomy, University of Nottingham, Nottingham, United Kingdom

We report on manipulating magnetocrystalline anisotropy via inverse magnetostriction on a picosecond time scale in a low-symmetry film of a magnetic metallic alloy galfenol (Fe,Ga). Two approaches are emploied, injection of a picosecond strain pulse into the film, and generation of a dynamical strain of a complex temporal profile in the film directly. In both cases the ultrafast change of magnetic anisotropy triggers magnetization precession owing to the mixed, compressive and shear, character of the dynamical strain emerging in the low-symmetry metallic film.

When optically-generated strain emerges abruptly in the film and modifies its magnetic anisotropy, it competes with heat-induced change of anisotropy. We show that optically-generated strain remains efficient for launching magnetization precession, when the heat-induced changes of anisotropy parameters do not trigger the precession any more.

Invited Talk MA 17.7 Tue 12:45 H 1012

Ultrafast Thermal Transport in Magnetic Heterostructures — •Richard Wilson[1], Michael Gomez[1], Jon Gorchon[2], Yang Yang[2], Charles-Henri Lambert[2], Sayeef Salahuddin[2], and Jeff Bokor[2] — [1]Materials Science and Engineering, University of California Riverside, Riverside, United States — [2]Electrical Engineering and Computer Sciences, University of California Berkeley, Berkeley, United States

Femtosecond heating of magnetic materials leads to a wide array of extraordinary thermally driven magnetic phenomena. Understanding and controlling ultrafast magnetic phenomena requires a detailed understanding of thermal transport in complex magnetic heterostructures. To achieve this understanding, we use a combination of TDTR and TRMOKE experiments to quantify thermal transport in magnetic heterostructures. We use ultrafast electrical or optical stimulus drive the heterostructures from thermal equilibrium. Then, we monitor tiny changes in optical and magneto-optic properties to monitor changes in temperature and magnetism. We interpret our data with spin and thermal transport models that quantify the diffusion of heat and spin across layers, as wells as energy flow between electronic-, vibrational-, and magnetic-degrees-of-freedom. Here, I discuss our recent efforts to understand ultrafast thermal phenomena in ferrimagnetic heterostructures. These experiments focus on both normal-metal/ferrimagnetic-metal heterostructures, e.g. Au/GdFeCo or Pt/GdFeCo, and normal-metal/ferrimagnetic-insulator heterostructures, e.g. Au/TmIG or Au/YIG.

MA 18: Multiferroics and magnetoelectrics I (joint session MA/KFM)

Time: Tuesday 9:30–12:15 Location: EB 202

MA 18.1 Tue 9:30 EB 202

Lu2Fe3O7 a quest for ferroelectricity by charge order — •Sabreen Hammouda and Manuel Angst — Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany.

Rare earth ferrites have attracted a lot of attention as proposed multiferroics. In particular, LuFe2O4 was considered a clear example of ferroelectricity from charge ordering (CO), though recently this was found not to be the case [1]. Structural modification, such as intercalation by LuFeO3, yielding Lu2Fe3O7 might render the bilayers polar. Furthermore, the only believable polarization hysteresis loop in the rare earth ferrite literature [2] was measured on an intercalated compound, slightly Mn-doped Lu2Fe3O7. A critical aspect of investigating these compounds is the oxygen-stoichiometry. We succeeded in growing single crystals of Lu2Fe3O7 using different CO2/CO gas mixtures to fine-tune the oxygen partial pressure. Single crystals examined by x-ray diffraction showed a short range ordering with a zigzagged diffuse scattering along (1/3 1/3 l), with positions similar to the observation by electron diffraction [3]. The diffuse nature indicates that the crystals are not quite stoichiometric enough for long range CO. Powder XRD measurements reveal a peak splitting which is likely due to structural distortion because of CO. Magnetic behavior of these crystals will also be discussed. As an outlook, further optimization is needed to determine the charge and spin structures. [1] de Groot et al., Phys. Rev. Lett. 108, 187601 (2012). [2] Qin et al., Appl. Phys. Lett. 95, 072901 (2009). [3] Yang et al., Phys. Status Solidi B 247, 870 (2010).

MA 18.2 Tue 9:45 EB 202

Structural and spectroscopic properties of the new multiferroic Ni_2MnTeO_6 — •Stella Skiadopoulou[1,2], Maria Retuerto[3], Fedir Borodavka[1], Christelle Kadlec[1], Filip Kadlec[1], Zheng Deng[3], Martha Greenblatt[3], Dominik Legut[2], and Stanislav Kamba[1] — [1]Institute of Physics of the Czech Academy of Sciences, Prague, Czech Republic — [2]VSB Techincal University of Ostrava, Ostrava, Czech Republic — [3]Rutgers, The State University of New Jersey, Piscataway, USA

We present structural, magnetic and spectroscopic studies of a new multiferroic Ni_2MnTeO_6, closely related to the polar antiferromagnet Ni_3TeO_6 known to present a colossal magnetoelectric effect and electromagnons. Single crystals and polycrystalline samples show the same polar structure as Ni_3TeO_6 with the R3 space group down to 4 K. An antiferromagnetic phase transition takes place at approximately T_N=70 K, almost 20 K higher than that of Ni_3TeO_6. This was confirmed by magnetic and dielectric measurements, suggesting the multiferroic character of the compound. Extensive infrared, Raman and THz spectroscopy experiments revealed all phonons predicted by the factor group analysis. THz spectra reveal one new excitation below T_N, which is strongly influenced by external magnetic field, thus assigned to a magnon.

This work was supported by Czech Science Foundation grant No. 17-27790S and Path to Exascale project No. CZ.02.1.01/0.0/0.0/16_013/0001791.

MA 18.3 Tue 10:00 EB 202

Exotic magnetoelectric excitations of the multiferroic SmFe3(BO3)4 — •Dávid Szaller[1], Artem M. Kuz'menko[2], Alexander A. Mukhin[2], Toomas Rõõm[3], Urmas Nagel[3], Thomas Kain[1], Vlad Dziom[1], Lukas Weymann[1], Alexey Shuvaev[1], Anna Pimenov[1], Vsevolod Yu. Ivanov[2], Irina A. Gudim[4], Leonard N. Bezmaternykh[4], and Andrei Pimenov[1] — [1]Institute of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia — [3]National Institute of Chemical Physics and Biophysics, Akadeemia tee 23, 12618 Tallinn, Estonia — [4]L. V. Kirensky Institute of Physics Siberian Branch of RAS, 660036 Krasnoyarsk, Russia

Magnetoelectric(ME) multiferroics(MFs), i.e. materials simultaneously hosting ferroelectric and magnetic order, have been attracting enormous interest due to their potential in information-technology applications. Rare-earth ferroborates are a particularly interesting familiy of MF crystals, where the strong spin-orbit interaction at the rare-earth sites results in the coupling of the magnetic and electric degrees of freedom while the ME response is enhanced by the antiferromagnetic ordering of the iron spins. The ME coupling appears in the optical regime as different absorption of counter-propagating light beams, where transparent and dark directions can be swapped by reversing the magnetic field. Furthermore, due to the ME coupling the strength of absorption at spin-wave resonance frequencies can also be tuned by electric field, opening the path for practical applications.

MA 18.4 Tue 10:15 EB 202

Low energy spin excitations in multiferroic $Mn_2Mo_3O_8$ — •Krisztián Szász[1], Dávid Szaller[2], Sándor Bordács[1], Laur Peedu[3], Johan Viirok[3], Toomas Rõõm[3], Urmas Nagel[3], Vladimir Tsurkan[4], and István Kézsmárki[1,4] — [1]Budapest University of Technology and Economics, Budapest, Hungary — [2]Vienna University of Technology, Vienna, Austria — [3]National Institute of Chemical Physics and Biophysics, Tallinn, Estonia — [4]University of Augsburg, Augsburg, Germany

Recently, it was found that the polar ferrimagnet $Mn_2Mo_3O_8$ shows large diagonal magnetoelectric effect [1]. However, the magnetic structure of this compound is not fully understood. The family of polar ferrimagnets $M_2Mo_3O_8$ with M = Mn, Fe, Co or Ni are excellent materials to investigate the role of different magnetic ions in the microscopic origin of magnetoelectric effect.

In this work magnetization measurements and high magnetic field far infrared spectroscopy are used to unreveal the spin excitations in the low-field ferrimagnetic and in the spin-flop phases. From the magnetic field dependence of the magnon excitation energies we aim to determine the most important exchange and anisotropy parameters. With these parameters it is possible to construct a microscopic spin model of this compound.

[1] T. Kurumaji et al.: PRB 95, 045142 (2017).

MA 18.5 Tue 10:30 EB 202

Local Magnetic and Electric Interactions in Multiferroic $Ba_2CoGe_2O_7$ and $Sr_2CoSi_2O_7$ — •Martina Schädler[1], Titusz Fehér[2], Norbert Büttgen[1], Vilmos Kocsis[3], Yoshinori Tokura[3], Yasujiro Taguchi[3], and István Kézsmárki[1] — [1]Center for Electronic Correlations and Magnetism, Institute of Physics, University of Augsburg, Germany — [2]Department of Physics, Budapest University of Technology and Economics, Hungary — [3]RIKEN Center for Emergent Matter Science, Wako 351-0198, Japan

The multiferroic compound $Ba_2CoGe_2O_7$ has drawn a lot of interest due to its non-centrosymmetric crystal structure, giving rise to peculiar magnetoelectric effects. The spin-dependent hybridization mechanism, that induces the electric polarization, results in a strong coupling of the magnetic moments and the local electric polarization, which allows control of the electric polarization via external magnetic fields. Due to its soft antiferromagnetic structure $Ba_2CoGe_2O_7$ is a promising candidate for tuning the magnetic texture via the application of electric fields. Nuclear Magnetic Resonance (NMR) gives access to the local electric field gradient (EFG) via the nuclear quadrupole moment. We performed ^{59}Co NMR measurements on $Ba_2CoGe_2O_7$ and its sister compound $Sr_2CoSi_2O_7$ in order to determine the local microscopic properties of magnetic spin order and electric polarization at the cobalt site. Through additional application of external electric fields we also investigated the possibility of influencing the local magnetic properties.

15 minutes break

MA 18.6 Tue 11:00 EB 202

Soft modes in $Ca_3Mn_2O_7$ - Direct observation of the order parameters in a hybrid improper ferroelectric material — •Dirk Wulferding[1,2], Alexander Glamazda[3,1], Peter Lemmens[1,2], Bin Gao[4], Sang-Wook Cheong[4], and Kwang-Yong Choi[5] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]LENA, TU-BS, Braunschweig, Germany — [3]ILTPE, NASU, Kharkov, Ukraine — [4]Rutgers Univ., New Jersey, USA — [5]Chung-Ang Univ., Seoul, Korea

In hybrid improper ferroelectric materials the order parameter is still under debate, but predicted to be a combination of rotation and tilting modes. In the title compound $Ca_3Mn_2O_7$ we observe anomalous softening of rotation and tilting phonons through the transition from the ferroelectric to the paraelectric phase. This clearly underlines their role as order parameters. In addition, a coupling of the soft mode to the magnetic and the electronic subsystems is characterized through an observation of anomalous magnetic and multiphonon Raman scattering. Work supported by the Quantum- and Nanometrology initiative "QUANOMET" within project NL-4, DFG-RTG 1952/1 "NanoMet", Korea NRF Grants (No. 2009-0093817, 2012-046138), and the NSF MRI Grant No. MRI-1532006.

MA 18.7 Tue 11:15 EB 202

Giant magnetoelectric coupling in the low-dimensional ferrimagnetic iron oxoselenite $Fe_2O(SeO_3)_2$ — •Peter Lemmens[1,2], Vladimir Gnezdilov[3], Dirk Wulferding[1,2], Peter Berdonosov[4], E.S. Kozlyakova[4], E. Kuznetsova[4], Olga Volkova[4], and Alexander Vasiliev[4] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]LENA, TU-BS, Braunschweig, Germany — [3]ILTPE, NASU, Kharkov, Ukraine — [4]MSU, Moscow, Russia

The newly synthesized oxoselenite compound $Fe_2O(SeO_3)_2$ hosts Fe ions in distorted tetrahedral coordination. An anomalous gain in phonon intensity observed within the ferromagnetically ordered phase ($T_C = 105$ K) hints towards an enhanced electronic polarizability and related giant magnetoelectric coupling. Further anomalous modes of possible magnetic origin are discussed in connection with a strong Dzyaloshinskii-Moriya interaction. Work supported by DFG Project LE967/16-1.

MA 18.8 Tue 11:30 EB 202

Magnetic and Polar Properties of the Lacunar Spinel $GaMo_4S_8$ — •Korbinian Geirhos[1], Peter Lunkenheimer[1], Hiroyuki Nakamura[2], Yoshikazu Tabata[2], and István Kézsmárki[1] — [1]Experimental Physics V, EKM, University of Augsburg, Germany — [2]Department of Materials Science and Engineering, Kyoto University, Japan

The compound $GaMo_4S_8$ belongs to the family of lacunar spinels AM_4X_8 (A=Ga and Ge; M=V, Mo, Nb, and Ta; X= S and Se). Many of these lacunar spinels exhibit a Jahn-Teller transition associated with ferroorbital ordering. In the so far investigated compounds GaV_4S_8, GaV_4Se_8 and GeV_4S_8, the onset of orbital-order induced ferroelectricity was found at the Jahn-Teller transition [1,2,3]. Moreover, all of these three materials show strong magnetoelectric coupling with distinct values of the polarization in their magnetically ordered phases, including a skyrmion lattice state, as shown for GaV_4S_8 and GaV_4Se_8 [1, 4]. It was proposed that these skyrmions, which are topologically protected spin textures, carry additional electric polarization [1]. We extend these investigations to another lacunar spinel, $GaMo_4S_8$. The polar properties of this compound were studied by dielectric spectroscopy and pyrocurrent measurements. It shows a Jahn-Teller transition at 47 K, again accompanied by polar ordering. In addition, below 20 K $GaMo_4S_8$ exhibits a complex magnetic phase diagram.

[1] E. Ruff *et al.*, Sci. Adv. **1**, E1500916 (2015). [2] E. Ruff *et al.*, Phys. Rev. B **96**, 165119 (2017). [3] K. Singh *et al.*, Phys. Rev. Lett. **113**, 137602 (2014). [4] Y. Fujima *et al.*, Phys. Rev. B **95**, 180410 (2017)

MA 18.9 Tue 11:45 EB 202

Ferrimagnetic-type in-gap spin excitations and magnetoelastic coupling in α-$Cu_2V_2O_7$ — •Johannes Werner[1], Liran Wang[1], Alexander Ottmann[1], Robin Weis[1], Mahmoud Abdel-Hafiez[2], Jhuma Sannigrahi[3], Souradip Majumdar[4], Changhyun Koo[1], and Rüdiger Klingeler[1] — [1]Kirchhoff Institute for Physics, Heidelberg, Germany — [2]Physikalisches Institut, Goethe-Universität, Frankfurt a.M., Germany — [3]ISIS Facility, Rutherford Appleton Laboratory, Didcot, United Kingdom — [4]Department of Solid State Physics, Kolkata, India

Low-energy magnetic excitations and magnetoelastic coupling in multiferroic α-$Cu_2V_2O_7$ have been investigated by high-frequency electron spin resonance (HF-ESR) , thermal expansion, magnetostriction, specific heat and magnetisation studies in magnetic fields up to 15 T. Despite a large antiferromagnetic gap, below 100 GHz we observe low-energy magnetic excitations in the spin ordered phase indicating a ferrimagnetic-type resonance branch associated with the Dzyaloshinsii-Moriya-type canted magnetic moment. The anisotropy parameter $\tilde{D} = 1.3(1)$ meV indicates a sizeable ratio of DM-exchange and magnetic anisotropy. Dilatometry results show negative thermal expansion at $T \leq 200$ K. Pronounced anomalies at $T_N = 35$ K imply coupling to the structure. Failure of Grüneisen scaling confirm that several ordering phenomena are concomitantly driving the multiferroic order. Low-field magnetostriction displays a similar hysteresis loop as the magnetisation which supports the scenario of exchange-striction driven multiferroicity.

MA 18.10 Tue 12:00 EB 202

Directional dichroism via para-magnetoelectric effect in $Sr_2CoSi_2O_7$ — •Dániel G. Farkas[1], Dávid Szaller[1], Vilmos Kocsis[1,2], Sándor Bordács[1], István Kézsmárki[1], Bence Bernáth[3], Dmytro Kamenskyi[3], Laur Peedu[4], Johan Viirok[4], Toomas Rõõm[4], Urmas Nagel[4], Péter Balla[5], and Karlo Penc[5] — [1]BUTE, Hungary — [2]RIKEN CEMS, Japan — [3]HFML, Netherlands — [4]KBFI, Estonia — [5]WRCP, Hungary

Magnetoelectric multiferroics have been attracting enormous interest due to their potential in information technology applications. An exotic phenomenon, directional dichroism (DD) has been reported for spin excitations in multiferroic melilite single crystals and proposed as a new principle of directional light switches operating in the THz region [1].

Applications of multiferroic compounds seem to be limited to low temperatures where electric and magnetic order coexist. However, recent studies on melilites [2] revealed that an external magnetic field can recover the electric polarization via the para-magnetoelectric effect even above $T_N = 7$ K. Based on these static results we can also expect DD to emerge in the paramagnetic phase of melilites.

Indeed we have found strong DD in the paramagnetic phase of $Sr_2CoSi_2O_7$ in high magnetic field. A simple single-ion model was developed, which described the main features of the high temperature directional dichroism.

[1] I. Kézsmárki, D. Szaller et al. Nat. Commun. 5, 3203 (2013).
[2] M. Akaki et al., Phys. Rev. B 86, 060413(R) (2012).

MA 19: Skyrmions II (joint session MA/TT/KFM)

Time: Tuesday 9:30–13:15 Location: EB 301

MA 19.1 Tue 9:30 EB 301

Low temperature magnetic field mapping on Néel-skyrmions in GaV4Se8 — •Franziska Seifert[1], Felix L. Kern[1], István Kézsmárki[2], Daniel Wolf[1], Bernd Büchner[1], and Axel Lubk[1] — [1]Leibniz Institute for Solid State and Materials research Dresden, Germany — [2]University of Augsburg, Germany

Skyrmions are promising candidates for magnetic memory devices, because of their small size, thermal stability and high mobility. Here we report on Skyrmion mapping in GaV4Se8 carried out on our dedicated cryo TEM fitted with a continuous-flow liquid He cryostat, facilitating electron holography and Lorentz TEM down to 7K. Bulk GaV4Se8 is predicted to show Neel type skyrmions below 18K under applied magnetic field between 0.10T and 0.45T mT. Using Lorentz TEM, we characterized the cycloidal and skyrmionic phase of thin GaV4Se8 lamellas in dependence of temperature and applied magnetic field. By mapping the magnetic phase diagram of the thin film we identify magnetic textures that are not considered in the bulk phase diagram. We discuss the origins of these in terms of crystal symmetries and strain prevailing in the thin film slab geometry.

MA 19.2 Tue 9:45 EB 301

Probing skyrmion lattice phase by NMR in GaV_4S_8 — •Markus Prinz-Zwick, Norbert Büttgen, Vladimir Tsurkan, Martina Schädler, and István Kézsmárki — Center of electronic correlation and magnetism, University of Augsburg

With the discovery of Néel-Type skyrmions forming in a skyrmion lattice (SkL) in the lacunar spinel GaV_4S_8, the characterization and analysis of such polar axially symmetric skyrmion host materials gained general interest. From a microscopic point of view we want to elucidate the local distribution of internal magnetic fields associated with the SkL and probe spin excitations using Nuclear Magnetic Resonance(NMR) spectroscopy. Since the stability of the SkL phase is limited to the sub-Tesla range, this is a highly challenging issue. Here, we report NMR results within the SkL-phase in the lacunar spinel GaV_4S_8, and the first so called zero-field NMR measurements, where the internal field of the V_4 cubanes was exploited to perform ^{51}V measurements for applied magnetic fields $0 < \mu_0 H < 100\,\mathrm{mT}$.

MA 19.3 Tue 10:00 EB 301

Optically induced demagnetization and coherent spin excitations in GaV4S8 — •Fumiya Sekiguchi[1], Prashant Padmanabhan[1], Rolf B. Versteeg[1], István Kézsmárki[2], and Paul H. M. van Loosdrecht[1] — [1]Institute of Physics 2, University of Cologne, 50937 Cologne, Germany — [2]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86135 Augsburg, Germany

Skyrmions are quasiparticle-like topological spin textures stabilized in non-centrosymmetric crystals with Dzyaloshinskii-Moriya interactions. For potential applications and a better understanding of their nature, it is important to understand their creation and annihilation dynamics, as well as their collective excitation spectrum. Here we employ time resolved magneto-optical Kerr experiments to study the magnetization dynamics in the lacunar spinel GaV4S8 which hosts novel cycloid and Néel-type skyrmion magnetic ground states. The experiments show the emergence of a slow demagnetization process in the magnetically ordered states. In addition, we observe coherent collective spin excitations in both the cycloid and skyrmion phases.

MA 19.4 Tue 10:15 EB 301

Temperature dependence of the cubic anisotropy in the room-temperature skyrmion host $Co_9Zn_9Mn_2$ — •Bertalan György Szigeti[1], Dieter Ehlers[2], Kosuke Karube[3], István Kézsmárki[2], Hans-Albrecht Krug von Nidda[2], Markus Preissinger[2], Vladimir Tsurkan[2], Yusuke Tokunaga[3], Yasujiro Taguchi[3], and Yoshinori Tokura[3] — [1]Department of Physics, Budapest University of Technology and Economics,1111 Budapest, Hungary — [2]Experimental Physik V, EKM, Universität Augsburg, 86135 Augsburg — [3]RIKEN Centre for Emergent Matter Science (CEMS), Wako 351-0198, Japan

The β-Mn-type Co-Zn-Mn alloys are cubic chiral room temperature skyrmion hosts already studied by Lorentz transmission electron microscopy, magnetization and small-angle neutron scattering[1]. Spin wave spectroscopy of the Dzyaloshinskii-Moriya interaction has been measured for $Co_8Zn_8Mn_4$ and $Co_9Zn_9Mn_2$[2]. $Co_9Zn_9Mn_2$ can host metastable skyrmions in zero magnetic field below its $T_C \approx 400$ K Curie-temperature[3]. In this work we present ESR measurements in the field polarized state of $Co_9Zn_9Mn_2$ to investigate the temperature dependence of the cubic magnetocrystalline anisotropy and its influence on the properties of the meta-stable skyrmion lattice state. We found strong correlation between the change in the anisotropy and the trigonal to square lattice transformation of the skyrmion state.

[1] Tokunaga, Y., et al., Nat. Commun. 6, 7638 (2015), [2] Takagi, R., et al., Phys. Rev. B 95, 220406 (2017), [3] Karube, K., et al., arXiv:1709.08047 (2017).

MA 19.5 Tue 10:30 EB 301

Effects of Magnetocrystalline Anisotropy on the Triangular to Square Lattice Transformation of Skyrmions — •Markus Preissinger[1], Dieter Ehlers[1], Kosuke Karube[2], István Kézsmárki[1], Hans-Albrecht Krug von Nidda[1], Bertalan Szigeti[3], Yusuke Tokunaga[2], Yasujiro Taguchi[2], Yoshinori Tokura[2], and Vladimir Tsurkan[1] — [1]Experimentalphysik V, EKM, Universität Augsburg, 86135 Augsburg — [2]RIKEN Centre for Emergent Matter Science (CEMS), Wako 351-0198, Japan — [3]Department of Physics, Budapest University of Technology and Economics, 1111 Budapest, Hungary

The β-manganese-type alloy $Co_8Zn_8Mn_4$ exhibits a helical state below the Curie-temperature $T_c \approx 300\,\mathrm{K}$ [1]. Below the phase transition, between 300 K and 284 K, an equilibrium skyrmion lattice state occurs in weak magnetic fields in the range of 400 Oe. This state can be quenched down to lower temperatures by rapid field cooling. Below 150 K the metastable triangular skyrmion lattice transforms into a square lattice [2]. The magnetocrystalline anisotropy in the ferromagnetic phase was determined by ferromagnetic resonance measurements. We discuss its impact on the phase transition between the two types of skyrmion lattices. On cooling, the increasing cubic anisotropy constant K_1 seems to drive the phase transition of the skyrmion lattice between 150 K and 40 K. The temperature dependence of the corresponding critical fields turns out to be correlated to the anisotropy constant K_1.

[1] T. Hori et al., J. Magn. Magn. Mater. **310**, 1820–1822 (2007).
[2] K. Karube et al., Nature Materials **15**, 1237–1243 (2016).

MA 19.6 Tue 10:45 EB 301

Incommensurate magnetic systems studied with the multipurpose three-axis spectrometer (TAS) MIRA at FRM II — •Robert Georgii[1], Tobias Weber[1,2], Georg Brandl[1], and Peter Böni[3] — [1]Maier-Leibnitz Zentrum (MLZ), Garching, Germany — [2]Institut Laue Langevin (ILL), Grenoble, France — [3]Physik Department E21, TU München, Garching, Germany

Incommensurate magnetic structures like Helimagnons and Skyrmions are currently intensively studied. Due to their large size and rigid structure they often show very low-lying excitations, where most of the interesting physics is taking place below some meV. The cold-neutron three-axis spectrometer MIRA is an instrument optimized for such low-energy excitations. Its excellent intrinsic resolution makes it ideal for studying incommensurate magnetic systems. Here we will present several examples for the dynamics of such structures which have been measured with MIRA.

MA 19.7 Tue 11:00 EB 301

Induction mapping of the 3D Spin Texture of Skyrmions in Thin Helimagnets — •Sebastian Schneider[1,2], Daniel Wolf[1], Matthew J. Stolt[3], Song Jin[3], Darius Pohl[1], Bernd Rellinghaus[1], Marcus Schmidt[4], Bernd Büchner[1], Sebastian T. B. Goennenwein[2], Kornelius Nielsch[1,2], and Axel Lubk[1] — [1]IFW Dresden, Dresden, Germany — [2]TU Dresden, Dresden, Germany — [3]University of Wisconsin-Madison, Madison, USA — [4]MPI CPfS, Dresden, Germany

Envisaged applications of skyrmions in magnetic memory and logic devices crucially depend on the stability and mobility of these topologically non-trivial magnetic textures in thin films. We present for the first time experimental evidence for a characteristic 3D modulation of the skyrmionic spin texture towards the sample surface. Inherent to this structure is the gradual change of the Bloch nature of the skyrmion in the depth of the film to surface chiral twists. By combining focal series inline electron holography (EH), and off-axis EH to quantitatively reconstruct the projected magnetic field pertaining to both the helical and the skyrmion lattice phase in single crystal nanoplates of the isotropic chiral magnet $Fe_{0.95}Co_{0.05}Ge$ nanoplate with electron tomography and magnetostatic simulations of the fields, we extract quantitative information on the 3D spin texture of skyrmions. Our results highlight the relevance of surfaces for the formation of skyrmions in thin film geometries and pave the way towards a surface-induced tailoring of the skyrmion structure.

15 minutes break

Topical Talk MA 19.8 Tue 11:30 EB 301

Composite topological excitations in ferromagnet-superconductor heterostructures — •Kjetil Hals — Department of Engineering Sciences, University of Agder, 4879 Grimstad, Norway

Heterostructures of conventional superconductors and ferromagnets are currently attracting considerable interest because of their potential use for realizing topological superconductivity. The combination of spin-orbit coupling in the superconductor and the lack of inversion symmetry of these heterostructures leads to a magnetoelectric coupling between the magnetic and superconducting order parameters [1, 2]. In this talk, I demonstrate that the magnetoelectric coupling causes magnetic skyrmions and superconducting vortices to bind, forming skyrmion-vortex pairs (SVPs) which represent topological excitations of the hybrid system [1]. I determine the conditions under which a bound SVP is formed, and characterize the range and depth of the effective binding potential through analytical estimates and numerical simulations. Furthermore, I develop a semiclassical description of the coupled skyrmion-vortex dynamics and discuss how SVPs can be controlled by applied spin currents.

[1] K.M.D. Hals, M. Schecter, M. S. Rudner, Phys. Rev. Lett. 117, 017001 (2016). [2] K. M. D. Hals, Phys. Rev. B 95, 134504 (2017).

MA 19.9 Tue 12:00 EB 301

Magnetoelectric effect and orbital magnetization in skyrmion crystals: new ways for detection and characterization of skyrmions — •Börge Göbel[1], Alexander Mook[2], Jürgen Henk[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle — [2]Institut für Physik, Martin-Luther-Universität, D-06120 Halle

Skyrmions are small magnetic quasiparticles, which are uniquely characterized by their topological charge and their helicity. We present theoretically how both properties can be determined without relying on real-space imaging [1].

The topological Hall effect of electrons allows to distinguish skyrmions from antiskyrmions by sign of the topological Hall conductivity [2,3] and the orbital magnetization [1]. Here, we predict a magnetoelectric effect in skyrmion crystals [1], which is the generation of a magnetization (polarization) by application of an electric (magnetic) field. Its dependence on the skyrmion helicity fits that of the classical toroidal moment of the spin texture and allows to differentiate skyrmion helicities: it is largest for Bloch skyrmions and zero for Néel skyrmions. We predict distinct features in the magnetoelectric polarizability that can be used to detect and characterize skyrmions in experiments.

[1] B. Göbel et al., submitted.
[2] B. Göbel et al., Phys. Rev. B **95**, 094413 (2017).
[3] B. Göbel et al., New J. Phys. **19**, 063042 (2017).

MA 19.10 Tue 12:15 EB 301

Antiferromagnetic skyrmion crystals: generation and topological spin Hall effect — •Börge Göbel[1], Alexander Mook[2], Jürgen Henk[2], and Ingrid Mertig[1,2] — [1]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle — [2]Institut für Physik, Martin-Luther-Universität, D-06120 Halle

Skyrmions are topologically nontrivial, magnetic quasi-particles, that are characterized by a topological charge. A regular array of skyrmions—a skyrmion crystal (SkX)—features the topological Hall effect (THE) of electrons [1,2], that, in turn, gives rise to the Hall effect of the skyrmions themselves.

We present a generally applicable method to create stable antiferromagnetic skyrmion crystals (AFM-SkXs) by growing a two-sublattice SkX onto a collinear antiferromagnet. As an example we show that both types of skyrmion crystals—conventional and antiferromagnetic—exist in honeycomb lattices. While AFM-SkXs do not show a THE, they exhibit a topological spin Hall effect [3]. The zero skyrmion Hall effect carries over to isolated AFM skyrmions as well. They can move in straight lines, at higher velocities and need lower driving currents compared to conventional skyrmions [4,5].

[1] B. Göbel et al., Phys. Rev. B **95**, 094413 (2017).
[2] B. Göbel et al., New J. Phys. **19**, 063042 (2017).
[3] B. Göbel et al., Phys. Rev. B **96**, 060406(R) (2017).
[4] J. Barker et al., Phys. Rev. Lett. **116**, 147203 (2016).
[5] X. Zhang et al., Sci. Rep. **6**, 24795 (2016).

MA 19.11 Tue 12:30 EB 301

Topological Hall effect in Heusler compound $Mn_{1.4}PtSn$ — •Praveen Vir, Nitesh Kumar, Chandra Shekhar, and Claudia Felser — Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Skyrmions are topologically stable vortex-like spin structure which are considered as potential candidate for future high density memory devices. They have been detected in many chiral and polar compounds such as MnSi, FeGe, Co-Mn-Zn, GaV_4S_8 etc. Recently, with the help of Lorentz transmission electron microscopy, one new vortex like spin structure, so called antiskyrmions have been discovered in Mn-based tetragonal Heusler compound $Mn_{1.4}PtSn$ and $Mn_{1.4}Pt_{0.9}Pd_{0.1}Sn$ [1]. Antiskyrmion has been predicted to be anti-particle of Néel or Bloch type skyrmions becuase they annihilate with conventional skyrmions [2]. They are also topologically stable and consist of topological winding number or skyrmion number +1 [3]. Due to this topologically stable spin nature, it can give rise to non-vanishing Berry phase in real space. In other words, there could be nonzero topological Hall effect. Here, we report large topological Hall effect in single crystal of antiskyrmion hosting compounds $Mn_{1.4}PtSn$.

MA 19.12 Tue 12:45 EB 301

Prospecting anti-skyrmions in ultra-thin Co films deposited on W(110) — •Flaviano José dos Santos, Bernd Zimmermann, Stefan Blügel, Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Recently, the possibility of anti-skyrmion formation in magnetic films on substrates with low symmetry due to anisotropic Dzyaloshinskii-Moriya interactions (DMI) has been demonstated [1]. Experimentally, such anisotropic DMI has been found for Co-films on W(110) [2]. Motivated by these findings, we investigated from first-principles the tensor of magnetic interactions of films containing up to three layers of Co reconstructed on W(110) surface as a continuation of our previous study [3]. We use the full-potential relativistic Korringa-Kohn-Rostoker Green function method combined with a technique employing infinitesimal rotations to access the different components of the tensor. The anisotropy, magnitude and sign of the interactions are analysed in detail with a focus on the DMI. Using atomistic spin dynamics simulations, we prospect and demonstrate the existence of skyrmions and anti-skyrmions, which depend strongly on the thickness of Co films. Finally, we unveil the spin-wave excitations characterising the topologically distinct skyrmionic objects.

Work supported by the Brazilian agency CAPES (Project No. 13703/13-7) and the European Research Council (ERC-consolidator Grant No. 681405-DYNASORE). [1] Nat. Commun. 8, 308 (2017); [2] Phys. Rev. B 95, 214422 (2017); [3] Phys. Rev. B 95, 134408 (2017).

MA 19.13 Tue 13:00 EB 301

Material systems for skyrmions in Co-based ferro-/antiferromagnetically (FM/AFM) coupled multilayers — •Hongying Jia, Bernd Zimmermann, Gustav Bihlmayer, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, D-52425 Jülich, Germany

Magnetic skyrmions, in particular AFM skyrmions, are considered as ideal candidates for high storage density information carriers due to the suppressed skyrmion Hall effect and a smaller size by canceling the dipolar fields. So far searching for materials that can host AFM skyrmions is still a challenging task. Magnetic multilayers (MMLs) with composite structures provide a great opportunity to design materials that can host spin-spirals, skyrmions or magnetic domains with optimal properties. Here we will present the qualitative trends of magnetic exchange interactions throughout a wide range of $\{Z|\text{Co}|\text{Pt}\}$

MMLs (Z=3d: Cu, Zn; 4d: Tc∼Cd; 5d: Au). The AFM coupling in between the Co layers was observed in {Z|Co|Pt} MMLs (Z=Zn, Ru, Rh, Cd). The effects of 3d-4d-5d hybridization between Co and the nonmagnetic metals, in particular the effects around the Fermi level, on the magnetic interactions will be discussed. The correlation between the electric interface dipole moments and the sign and magnitude of the Dzyaloshinskii-Moriya interaction will be also discussed.

We acknowledge financial support from the MAGicSky Horizon 2020 European Research FET Open project (#665095) and computing time at JURECA from Jülich Supercomputing Center and JARA-HPC.

MA 20: Magnetocaloric effects (joint session MA/TT)

Time: Tuesday 9:30–12:45 Location: EB 407

MA 20.1 Tue 9:30 EB 407

A DFT and Monte Carlo approach to simulating the magnetocaloric effect in magnetovolume-coupled materials —
•Nuno Fortunato[1,2], João Amaral[2], Gercsi Zsolt[3], João Gonçalves[2], Vitor Amaral[2], Hongbin Zhang[1], Oliver Gutfleisch[1], Vitalij Pecharsky[4], Karl Sandeman[5], and Lesley Cohen[5] — [1]TU Darmstadt, Germany — [2]CICECO, Universidade de Aveiro, Portugal — [3]Physics, Trinity College Dublin, Ireland — [4]Ames Laboratory, United States — [5]Department of Physics, Imperial College London, United Kingdom

Magnetic refrigeration is an emergent technology promising for eco-friendly and more energy efficient refrigeration applications, using the magnetocaloric effect (MCE). Magnetovolume effects contribute significantly to the MCE, however the estimation of MCE with magnetovolume effects remains a challenge. In this work, we simulate the MCE using a microscopic model solved by Monte Carlo methods that evaluate the thermodynamic density of states. The magnetic interaction (J_{ij}) between local moments is considered a function of volume (v), together with external field (H) and lattice volume terms: $H = -\frac{1}{2}\Sigma J_{ij}(v)S_i.S_j + \frac{1}{2}Kv^2 - HM$, where K is compressibility.

Simulation results are compared with the experimental data of Gd, the typical benchmark material for room-temperature magnetic cooling applications. We show that such a simple model quantitatively reproduces experimental data for the MCE and the magnetostriction. This work paves the way to a 'ground-up', fast computational approach to optimize and search for magnetic refrigerant materials.

MA 20.2 Tue 9:45 EB 407

Spin dynamics of magnetocaloric compounds under magnetic field investigated with inelastic neutron scattering measurements —
•Nikolaos Biniskos[1,2], Karin Schmalzl[1], Stephane Raymond[2], and Thomas Brückel[3] — [1]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science at ILL, 71 avenue des Martyrs, 38000 Grenoble, France — [2]Univ. Grenoble Alpes, CEA, INAC, MEM, 38000 Grenoble, France — [3]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT, 52425 Jülich, Germany

The magnetocaloric effect (MCE) is a temperature or entropy change of a material subject to a variation of magnetic field and is the basic principle of magnetic refrigeration. This technique is considered as promising for a more environmentally friendly and efficient use of energy. However, the microscopic mechanisms at play are to be revealed and the key ingredients are to be identified in order to design new materials. In order to understand the fundamental driving force of the MCE, a microscopic study of magnetism with inelastic neutron scattering (INS) measurements is necessary. To this aim, the spin dynamics of MnFe4Si3 and Mn5Si3, that exhibit the direct and inverse MCE, respectively, have been investigated with INS measurements under different magnetic fields and temperatures. It is evidenced that the inverse MCE of Mn5Si3, the cooling by adiabatic magnetization, is associated with field induced spin-fluctuations, contrary to the usual suppression of fluctuations by a magnetic field that is observed in the direct MCE of MnFe4Si3 [1]. [1]N. Biniskos et al., Phys. Rev. B 96 104407 (2017).

MA 20.3 Tue 10:00 EB 407

Element-specific view on La(FeSi)$_{13}$ —
•Katharina Ollefs[1], Markus E. Gruner[1], Fabrice Wilhelm[2], Andrei Rogalev[2], Ilya Radulov[3], Alexandra Terwey[1], Benedikt Eggert[1], Maria Krautz[4], Konstantin Skokov[3], Werner Keune[1], Oliver Gutfleisch[3], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg- Essen, Germany — [2]European Synchrotron Radiation Facility, Grenoble, France — [3]Functional Materials, Technical University Darmstadt, Darmstadt, Germany — [4]Institute for Complex Materials, IFW Dresden, Dresden, Germany

Due to its large magneto-caloric effect, the itinerant electron metamagnet La(FeSi)$_{13}$ is of great interest for its potential use in solid state refrigeration. In order to better understand the magnetic interactions in this material and how they change at the transition, we have performed x-ray absorption measurements. X-ray magnetic circular dichroism measurements in the low temperature phase at the Fe K-edge and La $L_{2,3}$-edges reveal not only a magnetic moment on Fe but also a sizable magnetic moment in the 5d states of La. Magneto-optical sum-rule analysis and DFT calculations indicate an anti-parallel alignement of the Fe and La spin moment and a small orbital moment on La also anti-parallel to spin moment. Disentangling the different magnetic moment contributions in La(FeSi)$_{13}$ may reveal additional sources for hysteresis and might shed light on the thermodynamic role of the particular magnetic degrees of freedom.

Funding by the DFG (SPP1599) is acknowledged.

MA 20.4 Tue 10:15 EB 407

Dynamic effects of the magneto-elastic phase transition in a Fe_2P-type magnetocaloric alloy —
•Maximilian Fries[1], Pfeuffer Lukas[1], Tino Gottschall[1,2], Franziska Scheibel[1,3], Konstantin Skokov[1], Youri Skourski[2], Mehmet Acet[3], Michael Farle[3], Jochen Wosnitza[3], and Oliver Gutfleisch[1] — [1]Institut für Materialwissenschaft, Technische Universität Darmstadt, 64287 Darmstadt — [2]Hochfeldlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden — [3]Fakultät für Physik und CENIDE, Universität Duisburg-Essen, 47057 Duisburg

Magnetic refrigeration could be an efficient alternative refrigeration technology if operated at high cycling frequencies [1]. In order to investigate if the magnetocaloric materials are applicable in a high-frequency cooling device we measured the adiabatic temperature change ΔT_{ad} of a Fe_2P-type alloy [2] under different field-change rates ranging from 0.93 Ts^{-1} in a permanent-magnet-based Halbach setup to 2700 Ts^{-1} in pulsed fields. We observed that a field-rate independent second-order like phase transition always overlaps with the first-order phase transition leading to a non-saturating behavior of ΔT_{ad} even in fields up to 20 T. By measurements under different field pulse rates we show that the first-order phase transition cannot follow the fast field changes, resulting in a distinct field-dependent hysteresis of ΔT_{ad}.

[1] O. Gutfleisch et al., Philosophical Transactions of the Royal Society A 374 (2016) 20150308. [2] M. Fries et al., Acta Materialia 132 (2017) 222

MA 20.5 Tue 10:30 EB 407

Decoupling of the magnetostructural transition in magntocaloric La-Fe-Si alloys —
•Yanyan Shao[1,2], Konstantin Skokov[2], Francois Guillou[3], Dmitriy Yu Karpenkov[2], Mingxiao Zhang[1], Oliver Gutfleisch[2], and Jian Liu[1] — [1]Ningbo Institute of Material Technology and Engineering, CAS, 315201 Ningbo, China — [2]Material Science, TU Darmstadt, 64287 Darmstadt, Germany — [3]European Synchrotron Radiation Facility, 38000 Grenoble, France

The giant magnetocaloric effect occurs when a magnetic material undergoes a first-order magnetic transition, which usually involves the coupling of magnetic and lattice contributions [1]. In order to investigate in detail the evolution of the magnetostructural phase transition, both magnetocaloric (dT(H)) and magnetovolume (dV(H)) effects in La1.7Fe11.6Si1.4 alloy were measured simultaneously. We observed that under isothermal conditions, only heat transfer occurs first, whereas the structural transition takes place in higher fields, where the heat transfer is already in progress or almost completed. The shift between the magnetic and structural transitions is 0.27 T, which clearly indicates a decoupling effect. The decoupling effect was also confirmed by X-ray absorption (lattice contribution) and by magnetic circular dichroism (change in magnetic system). We will discuss different reasons for the decoupling effect. [1]V. K. Pecharsky et al., Physical

Review Letters. 91 (2003) 197204.

MA 20.6 Tue 10:45 EB 407

Correlation of microstructural and magnetic properties of Mn-Fe-P-Si magnetocaloric compounds — •Lukas Pfeuffer[1], Maximilian Fries[1], Enrico Bruder[1], Tino Gottschall[2], Semih Ener[1], Léopold Diop[1], Thorsten Gröb[1], Konstantin Skokov[1], and Oliver Gutfleisch[1] — [1]Fachbereich Materialwissenschaft, TU Darmstadt, 64287, Darmstadt, Germany — [2]Dresden High Magnetic Field Laboratory, Helmholtz-Zentrum Dresden-Rossendorf, 01328, Dresden, Germany

Mn-Fe-P-Si alloys of Fe2P-type are very promising candidates for magnetocaloric applications. Extensive studies dealing with the optimization of the chemical composition have been published in recent years. However, the microstructure and its effect on the thermomagnetic properties are rarely discussed in literature. For this reason, we processed Mn-Fe-P-Si samples using a powder-metallurgical approach and characterized their microstructure and magnetocaloric behaviour. SEM, EDX, EBSD and XRD studies display small amounts of a cubic secondary phase showing a distinct phosphorous depletion and a characteristic arrangement at the triple junctions of the Fe2P grains. A shift in saturation magnetization, transition temperature and isothermal entropy change as a function of the secondary phase fraction can be observed. A significant influence of the metal/non-metal ratio on the above mentioned properties could be investigated. Additionally, all the prepared samples reveal a virgin effect shown thermomagnetically and with temperature dependent optical microscopy.

MA 20.7 Tue 11:00 EB 407

Influence of substitutions, hydrostatic pressure and magnetic field on the MnNiGe system — •Andreas Taubel, Tino Gottschall, Maximilian Fries, Tom Faske, Konstantin P. Skokov, and Oliver Gutfleisch — TU Darmstadt, Institute of Material Science, Alarich-Weiss-Str. 16, 64287 Darmstadt, Germany

An enhancement in the energy efficiency of cooling devices for household refrigeration and air conditioning can provide worldwide savings in energy and CO_2 emissions. An alternative to conventional gas compression refrigerators is solid state based magnetocaloric cooling with the potential of increased energy efficiency. The MM'X materials family provides promising magnetocaloric effects with sharp phase transitions for the MnNiGe and MnCoGe systems.

We studied the isostructural substitutions of Fe for Mn and Si for Ge, which enhance the ferromagnetic character of the low temperature phase, allow for a precise tuning of the transition temperature and reduce the amount of expensive Ge in the compounds. Since a magnetic field shifts the transition temperature by 1 K T^{-1}, the phase transition cannot be induced completely in small fields. We directly measured a maximum adiabatic temperature change of 1.3 K for the first magnetic field application of 1.93 T [1]. Therefore, the large sensitivity towards hydrostatic pressure (72 K GPa^{-1}) enables an additional stimulus to induce the phase transition more efficiently for Fe- and Si-substituted (Mn,Fe)Ni(Ge,Si) compounds.

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

[1] A. Taubel et al., J. Phys. D: Appl. Phys. 50, 464005 (2017)

15 minutes break

MA 20.8 Tue 11:30 EB 407

Exploring three-dimensional temperature gradients in magnetic tunnel junctions: Anomalous Nernst effect — Ulrike Martens[1], Torsten Huebner[2], Henning Ulrichs[3], Oliver Reimer[2], Timo Kuschel[2], Ronnie Tamming[4], Chia-Lin Chang[4], Raanan Tobey[4], Andy Thomas[5], Markus Münzenberg[1], and •Jakob Walowski[1] — [1]Universität Greifswald, Greifswald, Germany — [2]Bielefeld University, Bielefeld, Germany — [3]Universität Göttingen, Göttingen, Germany — [4]University of Groningen, Groningen, The Netherlands — [5]IFW Dresden, Institute for Metallic Materials, Dresden, Germany

We measure the anomalous Nernst effect (ANE) generated on a nanometer length scale by micrometer sized temperature gradients in magnetic tunnel junctions (MTJs). The ANE is extracted by analyzing the influence of in-plane temperature gradients on the tunnel magneto-Seebeck effect (TMS) in in-plane magnetized MTJs based on CoFeB electrodes with uniaxial magnetic anisotropy and an MgO tunnel barrier. The direction controlled temperature gradients are created by a focused laser spot. The spatial extent of the measured effects is defined by the MTJ size, while the spatial resolution is given by the laser spot size and the step size of its lateral translation. The measurement method is highly sensitive to low voltages and yields an ANE coefficient of $K_N \approx 1.6 \cdot 10^{-8} \frac{V}{TK}$ for CoFeB. At such sensitivity, the generated ANE effect allows to expand the MTJs' functionality from simple memory storage to nonvolatile logic devices and opens new application fields e.g. direction dependent temperature sensing.

MA 20.9 Tue 11:45 EB 407

Anomalous Nernst effect in carbon doped Mn_5Ge_3 and Mn_5Si_3 thin films — •Sasmita Srichandan, Sihao Deng, and Christoph Sürgers — Karlsruhe Institute of Technology, Physikalisches Institut, PO Box 6980, 76049 Karlsruhe, Germany

Carbon doped Mn_5Ge_3 shows enhanced magnetic properties compared to pure Mn_5Ge_3 which makes $Mn_5Ge_3C_x$ suitable for spintronics applications. The magnetotransport properties of ferromagnetic Mn_5Ge_3, $Mn_5Ge_3C_{0.8}$ and $Mn_5Si_3C_{0.8}$ systems have been previously investigated [1]. In this present work, the thermal-magnetotransport properties, in particular the anomalous Nernst effect (ANE), have been experimentally investigated in thin films of $Mn_5Ge_3C_{0.8}$, $Mn_5Si_3C_{0.8}$ and Mn_5Ge_3 on Ge (111). The ANE coefficients for all the films show the same positive sign at high temperatures until at about 100 K the sign changes to negative for $Mn_5Ge_3C_{0.8}$ and Mn_5Ge_3 films but not for $Mn_5Si_3C_{0.8}$ film. This behavior follows the same change of sign behavior previously observed in the anisotropic magnetoresistance ratio and ordinary Hall coefficient for these films. The change of sign of the ANE is the direct consequence of the Mott relation in our ferromagnetic films [2] even if the sign of the anomalous Hall coefficient remains unchanged. In addition, a possible contribution from the spin Seebeck effect to the transverse thermo-voltage has been addressed.

[1] C. Sürgers et al. Phys. Rev. B **90**, 104421(2014)
[2] T. Miyasato et al. Phys. Rev. Lett. **99**, 086602(2007)

MA 20.10 Tue 12:00 EB 407

An experimental design to measure the spin Nernst effect — •Sandra Gottwals[1], Thierry Crozes[2], and Georg Schmidt[1,3] — [1]Martin-Luther-Universität Halle-Wittenberg, Institut für Physik, Fachgruppe Nanostrukturierte Materialien, Halle — [2]Institut Néel, CNRS, Grenoble — [3]Martin-Luther-Universität Halle-Wittenberg, Interdisziplinäres Zentrum für Materialwissenschaften, Halle

Like the spin Hall effect to the ordinary Hall effect the spin Nernst effect compares to the Nernst effect. A thermal gradient in a material with sufficient spin orbit coupling generates a spin current and spin accumulation perpendicular to the gradient. We are developing a setup to measure the resulting spin accumulation and magnetic moment using micro SQUIDs. The sample design is rather complex because it needs at least two micro SQUIDs to measure the spin accumulation on two opposite sides of a Pt layer together with superconducting stripes to measure the local temperature. On top of these a Pt layer and a heater with the necessary electrical insulation need to be processed. We present the results and current status of our development. On all superconducting structures the critical current needs to be measured simultaneously.

MA 20.11 Tue 12:15 EB 407

A tool for detecting complex magnetic configurations — •Alexander Fernández Scarioni[1], David Schroeter[2], Xiukun Hu[1], Sibylle Sievers[1], Dirk Menzel[2], Stefan Süllow[2], and Hans W. Schumacher[1] — [1]Physikalish-Technische Bundesanstalt (PTB), Braunschweig, Germany — [2]Institut für Physik der Kondensierten Materie, TU Braunschweig, Germany

The anomalous Nernst effect (ANE) is a simple and powerful tool to detect the average magnetization in a single nanowire. Using this simple thermoelectrical measurement one can precisely track the position and motion of a single Domain Wall in a metallic nanowire with perpendicular magnetization anisotropy with a resolution below 20 nm [1]. This makes the ANE a candidate for detecting the magnetization in nanowires made of complex materials such as the ones that show a Dzyaloshinskii-Moriya Interaction (DMI), even also single skyrmions in nanowires. We are going to show thermoelectric ANE measurements on a nanowire with DMI were we can identify the different components of the magnetization.

[1] P. Krzysteczko et al., Phys. Rev. B. 95, 220410(R) (2017)

MA 20.12 Tue 12:30 EB 407

Magneto-Seebeck Tunneling Across a Vacuum Barrier — •Cody Friesen and Stefan Krause — Department of Physics, Uni-

versity of Hamburg, Jungiusstr. 11A, 20355 Hamburg, Germany

The tunneling magneto-Seebeck (TMS) effect has been intensively studied both for its potential applications in e.g. waste heat recycling in electronics, and for the insights it can provide into fundamental solid state phenomena. This effect has been measured in planar junctions [1] and, as will be described in this talk, can also be measured using spin-polarized scanning tunneling microscopy (SP-STM).

The experiments were performed at low temperatures ($T = 50\,\mathrm{K}$) and in UHV conditions, on the Fe/W(110) multilayer system [2], using a laser-heated bulk Cr tip and active bias compensation. The non-collinear spin structures present in this sample system, and the atomic-scale lateral resolution of SP-STM, allowed for the imaging of a continuous range of relative tip-sample magnetization orientations.

Here, as in planar junctions, the measurement of the temperature gradient between electrodes is a significant challenge. We have estimated the tip-sample temperature difference using a linear thermal tip expansion model. To verify this, we have also directly predicted the Seebeck coefficient S using tunneling bias spectroscopy. We found these approaches to be in good agreement, suggesting a convenient spectroscopic approach to determining S on the atomic scale, even in the absence of a temperature gradient.

[1] M. Walter *et al.*, Nat. Mater. **10**, 10 (2011).
[2] S. Meckler *et al.*, Phys. Rev. Lett. **103**, 15 (2009).

MA 21: Poster I

Time: Tuesday 9:30–13:00 Location: Poster A

MA 21.1 Tue 9:30 Poster A

Topological Hall effect in asymmetric all-oxide perovskite superlattices? — •Lena Wysocki, Jörg Schöpf, Ramil Mirzaagheyev, Rolf Versteeg, Paul H. M. van Loosdrecht, and Ionela Lindfors-Vrejoiu — Universität zu Köln, II. Physikalisches Institut

Interactions at coherent interfaces in all-oxide superlattices may result in spectacular physical effects. The presence of interfacial Dzyaloshinskii-Moriya interaction at the interface between a ferromagnetic oxide layer and a heavy 5d metal oxide may generates chiral magnetic order in the ferromagnetic layers, possibly even leading to a skyrmionic phase. Here we study the effects of interfacing a ferromagnetic 4d transition metal oxide, SrRuO3, with non-magnetic insulating 4d and 5d transition metal oxides. Asymmetric superlattices combining SrRuO3 and 5d perovskite oxides were grown by pulsed-laser deposition and studied by SQUID magnetization, magneto-optical Kerr effect, and Hall effect experiments. The Hall resistivity measurements of the superlattices showed, besides the usual ordinary and anomalous contributions, a clear contribution hinting to the occurrence of a topological Hall effect, and hence to the occurrence of topological magnetic textures in the SrRuO3 layers. These results open the gateway to engineered all-oxide heterostructures hosting non-trivial magnetic structures such as skyrmions.

MA 21.2 Tue 9:30 Poster A

Signatures of toroidal order — •Oliver Busch[1], Börge Göbel[2], and Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität, D-06120 Halle — [2]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle

Magnetic moments that form a closed planar ring exhibit a toroidal moment. Ferrotoroidic order, i. e., the periodic arrangement of uniform toroidal moments, changes its sign upon application of space or time inversion and gives rise to a magnetoelectric effect of electrons [1]. Effective Hamiltonians allow a simplified description of toroidal order on honeycomb lattices and a prediction of the magnetoelectric effect, as well as a strongly diminished anomalous Hall effect in the presence of toroidal order [2].

We report on tight-binding calculations of a full *sp* Hamiltonian with toroidal order on a square-octagon lattice, in which toroidal moments are formed by the four spins of the square plaquettes. The band structure of electrons on this lattice without toroidal order shows a symmetric shift in reciprocal space due to spin-orbit coupling. Applying toroidal order leads to an asymmetric shift along the direction of the toroidal moment, as for the honeycomb lattice [2]. We present a band-resolved analysis to obtain deeper understanding of the above effects.

[1] N. Spaldin et al., J. Phys.: Condens. Matter **20**, 434203 (2008).
[2] S. Hayami et al., Phys. Rev. B **90**, 024432 (2014).

MA 21.3 Tue 9:30 Poster A

Spin-resolved inelastic electron scattering by spin-waves in non-collinear magnets — •Flaviano José dos Santos, Manuel dos Santos Dias, Filipe S.M. Guimarães, Juba Bouaziz, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

So far, no experimental technique has attempted to probe large wave-vector spin-waves in non-collinear low-dimensional systems. In this work, we explain how inelastic electron scattering, being suitable for investigations of surfaces and thin films, can detect the collective spin-excitation spectra of non-collinear magnets. We propose a measurement protocol to reveal the particularities of spin-waves in such non-collinear samples, by utilizing spin-polarized electron-energy-loss spectroscopy augmented with a spin-analyzer. With the spin-analyzer detecting the polarization of the scattered electrons, four spin-dependent scattering channels are defined, which allow to filter and select specific spin-wave modes. We take as examples a topological non-trivial skyrmion lattice, a spin-spiral phase and the conventional ferromagnet. Then we demonstrate that, counter-intuitively and in contrast to the ferromagnetic case, even non spin-flip processes can generate spin-waves in non-collinear substrates.

Work supported by the Brazilian agency CAPES under Project No. 13703/13-7 and the European Research Council under ERC-consolidator Grant No. 681405-DYNASORE.

MA 21.4 Tue 9:30 Poster A

Spin wave dynamics in the chiral magnet $Fe_{50}Ge_{50}$ — •Nicolas Josten[1], Benjamin Zingsem[1,2], Detlef Spoddig[1], Iliya Radulov[3], Ralf Meckenstock[1], Thomas Feggeler[1], Michael Farle[1], and Oliver Gutfleisch[3] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University Duisburg Essen, Duisburg, 47057, Germany — [2]Ernst Ruska Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [3]Department of Material- and Geosciences, Functional Materials, Technische Universität Darmstadt

We use X-band ferromagnetic resonance (FMR) spectroscopy inside an R-Type micro-resonator [1] to investigate polycrystalline micron sized samples of $Fe_{50}Ge_{50}$, a chiral magnet, with a B20 crystal structure. Unusual dynamics in confined chiral magnets were, for example, predicted in [2], showing that additional resonance modes are expected in confined chiral systems as opposed to achiral systems. Indeed, besides the uniform main mode, we observe a multitude of resonances at high fields (200-900 mT), identified as spin wave modes, which cannot be explained within the standard model of FMR and are tailorable in wedge-shaped samples due to the special geometric boundary conditions. Furthermore, we find a unidirectional anisotropy for the spin waves, which does not affect the uniform main mode.

[1] R. Narkowicz, D. Suter, and I. Niemeyer. Rev. of Sci. Instr., 79(8):084702, 2008. [2] B. Zingsem, M. Farle, R. Stamps, R. Camley. arXiv:1609.03417

MA 21.5 Tue 9:30 Poster A

Resonant Soft X-Ray Scattering Ferromagnetic Resonance in the chiral magnet Cu_2OSeO_3 — •Simon Pöllath[1], Aqeel Aisha[1], Chen Luo[1,2], Hanjo Ryll[2], Florin Radu[2], and Christian Back[1] — [1]Department of Physics, University of Regensburg, Universitätsstrasse 31, 93053, Regensburg, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein Str. 15, 12489, Berlin, Germany

We report on X-ray Ferromagnetic Resonance (X-FMR) in scattering geometry in the skyrmion hosting chiral magnet Cu_2OSeO_3. Using a detector system which provides vertical and horizontal scanning capability mounted within the magnet bore, the diffraction patterns of the helical, conical and skyrmion phases are obtained. Through mapping of the magnetic scattering around the forbidden structural (001/2) Bragg peak, in resonant scattering at the Cu L_3 edge, we can distinguish and probe individually each of the helical, conical and skyrmion magnetic configurations. The system is excited via microwaves which at the resonant frequencies is directly as magnetic scattering contrast. The measurements were performed at the VEKMAG end station.

MA 21.6 Tue 9:30 Poster A

generation of dzyaloshinskii-moriya interaction in three-dimensional topological insulators beyond linear indirect exchange interaction — •Mahroo Shiranzaei[1,2], Jonas Fransson[2], Hosein Cheraghchi[1], and Fariborz Parhizgar[2] — [1]School of Physics, Damghan University, P.O. Box 36716-41167, Damghan, Iran — [2]Department of Physics and Astronomy, Uppsala University, Box 516, SE-751 21, Uppsala, Sweden

The Dzyalosinski-Morya (DM) interaction which is a cause of spin-orbit coupling in materials becomes a rapidly growing topic in the field of spintronics. This anisotropic interaction results in exotic phases such as skyrmions, and chiral domain walls. In dilute magnetic semiconductors, the magnetic impurities interact indirectly via the itinerant electrons and the magnetic properties can be controlled by tuning the electronic properties. Although the surface states of three-dimensional topological insulators resemble a pure Rashba Hamiltonian, the DM term takes zero magnitude at the Dirac point. Furthermore, impurities modify the electronic structure by inducing new local states in the material. These new states become important when they occur at energies with vanishing (inside band gap) or low density of electron states (e.g., near Dirac point). In our survey, we go beyond the well-known RKKY interaction within the linear response theory and consider effects of these impurity states on the indirect exchange interaction. We studied the effect of these new states on the different terms of the RKKY interaction and found that the DM term takes large values while the collinear parts reduce and even can change sign in some cases.

MA 21.7 Tue 9:30 Poster A

Spin textures in Fe/Rh/Ir(111) investigated by spin-polarized STM — •Andre Kubetzka, Kirsten von Bergmann, and Roland Wiesendanger — Department of Physics, University of Hamburg, Germany

We employ low temperature spin-polarized STM to investigate heterogeneous bilayer films on the heavy substrate Ir(111). While Pd/Fe/Ir(111) shows a magnetic spin spiral of 6 nm, which forms a skyrmion lattice in an applied field of 1.5 Tesla [1], exchanging Pd with Rh results in spiral periods of only 1-1.5 nm in Rh/Fe/Ir(111) [2]. Here, we investigate the magnetism of the reversed system, Fe/Rh/Ir(111), where the Fe layer is moved away from the heavy substrate. Depending on the stacking of the Fe layer (hcp or fcc), we find a spiral of period 1.1 nm and a hexagonal spin texture with a period of 1.3 nm. The magnetic periods are surprisingly close to the reversed system, Rh/Fe/Ir(111), but interestingly, the stacking of the Fe layer alone determines whether the spin texture is one- or two-dimensional.

[1] N. Romming *et. al*, Writing and deleting single magnetic skyrmions, Science **341**, 636 (2013).
[2] N. Romming *et. al*, Spin spirals in ultra-thin films driven by frustration of exchange interactions: Rh/Fe/Ir(111), arXiv:1610.07853 (2016).

MA 21.8 Tue 9:30 Poster A

Stripe and bubble domain formation and transformation in Ni/Fe/Cu(001) — •Thomas Meier, Matthias Kronseder, and Christian Back — Institut für experimentelle und angewandte Physik, Universität Regensburg, Deutschland

In ultrathin ferromagnetic films with perpendicular magnetic anisotropy a spin-reorientation transition from out-of-plane to in-plane magnetization may occur. The competition of the domain wall energy and the dipole interaction leads to a rich variety of domain patterns in the vicinity of this spin reorientation transition. We investigate chiral magnetic domain patterns stabilized by the Dzyaloshinskii-Moriya interaction (DMI) in Cu- and Pt- capped Ni/Fe/Cu(001) samples with different DMI-constants depending on effective anisotropy, temperature and external magnetic fields. Phase diagrams of the magnetic domain pattern are recorded for both sample types and by scaling the magnetic field a universal phase diagram for perpendicularly magnetized systems depending only on the stripe domain width in zero field and the external magnetic field is obtained. By real-time imaging of the domain pattern using a high-speed camera we investigate the transition between bubble and stripe domain patterns dependent on external magnetic field and temperature. We found that due to the chiral nature of the domain walls merging and splitting of stripe segments may be strongly suppressed at room temperature depending on the stripe width, whereas a larger temperature of approx. 90°C allows the transformation from bubbles to stripes and vice versa in an experimentally accessible time scale.

MA 21.9 Tue 9:30 Poster A

Modification of perpendicular anisotropy synthetic antiferromagnets by local ion irradiation — •Fabian Samad[1], Leopold Koch[1,2], Phani Arekapudi[1], Miriam Lenz[2], and Olav Hellwig[1,2] — [1]Institute of Physics, Chemnitz University of Technology, Germany — [2]Institute for Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Germany

By using local ion irradiation we modify the magnetic microstructure of perpendicular anisotropy synthetic antiferromagnets (AF) consisting of [(Co/Pt)Co/Ru] multilayers. The systems magnetic energy balance between AF interlayer exchange and dipolar energy has been tuned such that its room temperature ground state exhibits a laterally correlated and vertically anti-correlated magnetic microstructure (single domain antiferromagnet) [1]. In our study we locally altered this energy balance with focused ion beam irradiation with different ion fluences and area shapes, giving rise to a variety of laterally coexisting magnetic phases and 3D-magnetic textures. Extensive studies of their interaction as well as their field reversal behavior were performed with in-field high resolution magnetic force microscopy.

[1] O. Hellwig, J. B. Kortright, A. Berger and E. E. Fullerton, J. Magn. Magn. Mater. 319, 13-55 (2007).

MA 21.10 Tue 9:30 Poster A

Surface acoustic wave mediated magneto elastic investigation of magnetic thin film systems — •Matthias Küss[1], Michael Heigl[2], Andreas Hörner[1], Manfred Albrecht[2], and Achim Wixforth[1] — [1]Lehrstuhl für Experimentalphysik I, Universität Augsburg, — [2]Lehrstuhl für Experimentalphysik IV, Universität Augsburg

Magnetostriction describes the geometrical deformation of a magnet, caused by an applied magnetic field. The effect vice versa is named inverse magnetostriction. This mechanism in combination with surface acoustic strain waves (SAW) enables the manipulation of the magnetization on short time scales (∼ ns) and on micrometer distances. Since the SAW and magnonic modes are typically excited in the same radio frequency regime, both degrees of freedom have the potential to become strongly or even resonantly coupled. Therefore, not only the magnetization, but also the properties of the SAW itself are characteristically changed. This can be easily measured in a delay line setup, made up of two interdigital transducers (IDT).

Besides highly magnetostrictive ferrimagnetic TbFe thin films, exchanged-biased CoFeB/CoO, consisting of a soft ferromagnet CoFeB and an antiferromagnetic CoO layer, are studied. Because the Néel temperature of the antiferromagnet is at about 160K, it is possible to probe the impact of the exchange bias effect on the magnetoacoustic interaction below and above the blocking temperature. First results obtained on magnetization reversal at room temperature as a function of sample orientation show good accordance with the theory of elastically driven ferromagnetic resonance.

MA 21.11 Tue 9:30 Poster A

Interfacial ferromagnetism in $LaMnO_3/SrMnO_3$ superlattices — •Jan Philipp Bange[1], Marius Keunecke[1], Vladimir Roddatis[2], and Vasily Moshnyaga[1] — [1]Erstes Physikalisches Institut, Georg-August-Universität-Göttingen, Germany — [2]Institut für Materialphysik, Georg-August-Universität-Göttingen, Germany

Transition-metal-oxide perovskite heterostructures show unusual electrical and magnetic properties originated from the so called “emergent phases” at the interfaces [1]. Their behaviour is shown to be governed by interfacial charge transfer, driven by polar mismatch and orbital reconstruction, which can be as well influenced by epitaxy stress. The metalorganic aerosol deposition (MAD) technique was employed to grow digital $[(SrMnO_3)_n/(LaMnO_3)_m]_{10}$ superlattices (SL) on $SrTiO_3(100)$ substrates with layer thicknesses n,m=3,4,5,6 u.c. Structural characterization reveals chemically sharp and symmetric interfaces as well as atomically smooth surface morphology. A complex magnetic behaviour with coexisting high- and low-temperature ferromagnetic phases with $T_{C,1}$=270-350 K and $T_{C,2}$=150-280 K, respectively, was observed and assigned to the interfacial ($T_{C,1}$) and LMO-like ($T_{C,2}$) contributions. Magnetic properties were found to be controlled by the SL design, i.e. by the SMO/LMO thickness ratio ($n/n+m$), thus, pointing out the importance of crystal structure and MnO_6 octahedral distortions onto the manifestation of the emergent high-T_C interfacial magnetism. [1] Hwang, H.Y., Iwasa, Y., Kawasaki, M., Keimer, B., Nagaosa, N. and Tokura, Y. "Emergent phenomena at oxide interfaces" *Nat. Mater.* **11**, 103 (2012).

MA 21.12 Tue 9:30 Poster A

Optical detection of magnetic excitations in ferromagnets via photoluminescence in nearby diamond NV centers — •Chris Körner[1], Martin Wagener[2], Niklas Liebing[1], and Georg Woltersdorf[1] — [1]Martin Luther University Halle-Wittenberg — [2]Johannes Gutenberg University Mainz

We detect magnetic resonance in ferromagnetic layers by means of optical photoluminescence (PL) measurements using nanoscale diamonds containing nitrogen-vacancy (NV) centers. In magnetic layers exposed to RF- and static bias fields, different modes can be excited. These modes become visible in the PL signal of nearby NV centers, as previously observed by Wolfe et al. [1,2]. However, the physical origin of the cross coupling between magnetic excitations and the photoluminescence of NV centers is still not revealed. There are some approaches conceivable, namely spin-transport, magnetostriction, and magnetic stray fields [3]. Our work intends to identify the physical mechanism of the spin-wave induced change in the PL signal by measuring the dependence on the excited modes in various magnetic materials at different RF-frequencies and bias fields. Additionally, we investigate the influence of different spacer layer materials and thicknesses, as well as various surface structures.

[1] C. S. Wolfe et al. Phys. Rev. B 89, 180406 (2014)
[2] C. S. Wolfe et al. ArXiv 1512.05418v2 (2016)
[3] A. Yacoby et al. Science 257, 6347 (2017)

MA 21.13 Tue 9:30 Poster A

X-ray magnetic linear dichroism as a probe for non-collinear magnetic state — •Chen Luo[1,2] and Florin Radu[2] — [1]Department of Physics, University of Regensburg, Universitätsstrasse 31, 93053, Regensburg, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein Str. 15, 12489, Berlin, Germany

We report on exploiting the X-ray magnetic linear dichroism (XMLD) contrast for probing the non-collinear states in $DyCo_5$ ferrimagnetic thin film. From the X-ray magnetic circular dichroism measurements, an anomalous 'wing shape' hysteresis loop is observed slightly above its compensation temperature. This bear the chracterisitcs of an intrinsic exchange bias effect, referred to as *atomic exchange bias.* This effect is assumed to be mediated by the formation of an the out-of-plane domain wall formation from the surface towards the bulk. By taking advantage of the strong linear dichroism of the Dy element at the M_5 absorption edge, the formation of domain walls during the hysteresis measurements is directly observed via XMLD measurements.

MA 21.14 Tue 9:30 Poster A

Novel method of setting exchange bias in tunnel magnetoresistance devices with laser annealing — •Apoorva Sharma[1], Maria Almeida[1,2], Sandra Busse[3], Mathias Müller[3], Patrick Matthes[2], Horst Exner[3], Stefan E. Schulz[2], Dietrich R.T. Zahn[1], and Georgeta Salvan[1] — [1]Institute of Physics, Chemnitz University of Technology, 09107 Chemnitz, Germany — [2]Fraunhofer ENAS, 09126 Chemnitz, Germany — [3]Laserinstitut Hochschule Mittweid, Schillerstraße 10, 09648 Mittweida, Germany

Magnetic field sensors have become indispensable in a vast variety of modern devices, with applications ranging from basic research to industrial equipment. The so-called spintronic magnetoresistive effects, in particular the tunnel magnetoresistance can provide larger signal yields and sensitivities compared to well-established Hall and Anisotropy magnetoresistance technologies. The selective orientation of the magnetization depending on setting an exchange bias in micron size sensors, however, still represents a challenge. This can be achieved by laser annealing in conjunction with the suitable magnetic field. We investigated micromagnetic properties of IrMn/CoFeB/MgO/CoFeB tunnel junctions upon localized annealing with a 1064 nm IR laser, focusing on the magnetic properties of the exchanged coupled IrMn/CoFeB bilayers, namely the magnetization, coercivity, and exchange bias field. These were evaluated with SQUID-VSM and MOKE-magnetometry, as well as with a 4-point probe magnetoresistance measurement method. The exchange field set with laser-field-cooling was observed to be comparable with conventional methods.

MA 21.15 Tue 9:30 Poster A

Influence of Bulk and Interface Defects in the Antiferromagnetic Layer for the Exchange- Bias Effect — •Tauqir Tauqir[1], M. Yaqoob Khan[2], Ikram Ullah[2], M. Sajjad[2], Izran Ullah[2], Yasser A. Shokr[1], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Kohat University of Science and Technology, Kohat 26000, Khyber Pakhtunkhwa, Pakistan

A series of experiments is carried out to identify the fundamental mechanisms leading to the exchange bias effect in ultrathin epitaxial bilayer samples ferromagnetic/antiferromagnetic (FM/AFM) on a $Cu_3Au(001)$ substrate. The studied samples are bilayers of single-crystalline antiferromagnetic $Ni_{25}Mn_{75}$ and ferromagnetic Co layers, deposited under UHV, in which structural or chemical defects are deliberately introduced by Ar^+ ion bombardment for short times at the FM/AFM interface or at a certain depth of the AFM layer. The approach is to influence both the interface coupling as well as the pinning sites inside the AFM material by the controlled insertion of disorder. Comparison of the magnetic properties measured by magneto-optical Kerr effect then allows a precise determination of the influence of the Ar^+ ion bombardment of the AFM layer. We find that the interfacial and sandwiched defects result in decrease and increase of the exchange bias field (H_{eb}), respectively. We interpret this as, within the AFM layer, sandwiched defects leading to the formation of domains, which in turn give rise to uncompensated pinned moments that are responsible for the increased H_{eb} as predicted in the domain-state model.

MA 21.16 Tue 9:30 Poster A

Interface coupling between 3*d*-$La_{0.67}Sr_{0.33}MnO_3$ and 5*d*-$SrIrO_3$ — •Lukas Bergmann, Diana Rata, and Kathrin Dörr — MLU Halle-Wittenberg, Halle, Germany

The magnetic anisotropy (MA) is a fundamental property of magnetic materials. Especially the perpendicular magnetic anisotropy (PMA) is important for new spintronic devices. We investigate how the interface coupling between 3d-$La_{0.67}Sr_{0.33}MnO_3$(LSMO) and 5d-$SrIrO_3$ (SIO) can influence the MA in the ferromagnetic LSMO. SIO is a paramagnet with a strong spin-orbit coupling [1], which can induce Dzyaloshinskii-Moriya interactions at the interface with another oxide.

Heterostructures of LSMO and SIO with different layer thickness are grown by the pulsed laser deposition (PLD). We are using TiO_2 terminated (100) $SrTiO_3$ as substrate. The structure characterization is done by X-Ray diffraction (XRD). The magnetic and electrical properties are investigated by SQUID and transport measurements. The results of this study and ongoing work will be presented.

[1] A. Biswas, K.-S. Kim, and Y. Jeong, Journal of Magnetism and Magnetic Materials, 400 (2015)

MA 21.17 Tue 9:30 Poster A

Ferromagnetic Resonance of Co_2MnGa Thin Films — •Peter Swekis[1,2], Anastasios Markou[1], Yi-Cheng Chen[1], Jörg Sichelschmidt[1], Stefan Klingler[3,4], Mathias Weiler[3,4], Sebastian T.B. Gönnenwein[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Straße 40, 01187 Dresden, Germany — [2]TU Dresden, Institute of Solid State Physics, Helmholzstr. 40, 01069 Dresden, Germany — [3]Walther Meißner Institute, Walther-Meißner-Straße 8, 85748 Garching, Germany — [4]TU München, Physics-Department, 85748 Garching, Germany

Heusler compounds are a widely studied class of materials interesting for spintronic applications due to a number of magnetic and electronic properties, such as high spin polarization and elevated Curie temperatures. The dynamic response to gigahertz frequencies becomes particularly interesting and has to be investigated in relevant structures. We studied Co_2MnGa thin films of various thicknesses (10-80 nm) with cavity FMR (X-Band) as well as broadband FMR to determine damping, g-factor, effective magnetization and anisotropy constants. First results show a trend of all parameters with changing thickness. Furthermore, we observed unusual oscillating behavior of the broadband FMR linewidth with frequency as well as 8-fold symmetry of the anisotropy in cavity FMR in-plane measurements.

MA 21.18 Tue 9:30 Poster A

XRMR study of ultrathin magnetite films on MgO and $SrTiO_3$ substrates — •Tobias Pohlmann[1], Karsten Küpper[1], Timo Kuschel[2], and Joachim Wollschläger[1] — [1]Osnabrück University, Osnabrück, Germany — [2]Bielefeld University, Bielefeld, Germany

Magnetite thin films are frequently discussed as material for spintronic devices, such as magnetic tunnel junctions. For such multilayer devices, understanding the magnetic interface effects can be significantly important. While x-ray magnetic circular dichroism (XMCD) – the main technique to investigate the magnetic properties in an element resolved fashion – is sensitive to the entire film volume, x-ray magnetic reflectometry (XRMR) allows for the probing of the magnetic moment depth distribution and even of buried interfaces. Recently, it has been found that the easy axis of magnetite films depends on the substrate, switching from [110] in Fe_3O_4/MgO(001) to [100] in $Fe_3O_4/SrTiO_3$(001) [1]. To clarify the origin of this behaviour, we have grown magnetite ultrathin films on MgO(001) and $SrTiO_3$(001) substrates by molecular beam epitaxy. We employ XMCD together with XRMR to obtain magnetic depth profiles of these samples. By selecting the Fe $L_{2,3}$ resonances, the impact of the subtrate choice on magnetite's differently coordinated Fe ions can be resolved. Magnetite's large saturation moment of 4 $\mu_B/f.u.$ leads to asymmetry ratios of the XRMR signals as high as 60% at the resonances, demonstrating the capability of this method for the study of magnetite.

[1] K. Küpper et al., PRB **94**, 024401 (2016)

MA 21.19 Tue 9:30 Poster A

Magnetization profile at the interface between CoFeB and MgO determined by XRMR — •Eberhard Goering, Daan Boltje, and Gisela Schuetz — Max-Planck-Institut für Intelligente Systeme, 70569 Stuttgart

Sputtered CoFeB films sharing an interface with MgO play a key role in out-of-plane magnetized magnetic tunnel junctions STT-MRAM devices, based on perpendicular magnetic anisotropy (PMA). It is possible to switch the magnetic configuration using an electric field, directly affecting the PMA in the CoFeB layer [1].

Detailed information on the chemical dependant near the interface magnetic profile still lacks. We have performed x-ray resonant magnetic reflectometry (XRMR) and related x-ray magnetic circular dichroism (XMCD) experiments on the CoFeB-MgO system [2]. We obtain magneto optical properties and corresponding chemical and magnetic profiles for Co and Fe separately.

Partial oxidation of Fe during microfabrication is reported, where the oxidation state is reversibly controlled by an electric field [3]. Similarly, we find a 1 nm iron dead layer at the MgO interface and a 0.4 nm thick dead layer for cobalt at both interfaces of the CoFeB. Our results provide more information on the changes in magnetization profile due to oxidation.

[1] Wang *et al.*, Nature Materials **11**, 64 (2012).
[2] Macke *et al.*, JoP: Condensed Matter **26**, 363201 (2014).
[3] Bonell *et al.*, Applied Physics Letters **102**, 152401 (2013).

MA 21.20 Tue 9:30 Poster A

Magnetic exchange coupling in Fe_3O_4/CoO bilayers on MgO(001) — •Kevin Ruwisch, Jari Rodewald, and Joachim Wollschläger — Fachbereich Physik, Universität Osnabrück, Barbarastr. 7, 49079 Osnabrück

Spintronics is a rising field of research in physics. Magnetite as a ferrimagnet and cobaltoxide as an antiferromagnet have become more important for industrial applications in spintronics over the years. For instance, magnetite is used in magnetoresistive random-access memory (MRAM) consisting of magnetic tunnel junctions (MTJ). Thus, improving the magnetic properties of ferrimagnetic films and ferrimagnetic/antiferromagnetic bilayers for spintronic devices is very important since antiferromagnetic films serve as pinning layers due to exchange bias.

Hence, in this work CoO and Fe_3O_4/CoO bilayers, grown by reactive molecular beam epitaxy (RMBE) on MgO(001), are investigated temperature-dependent via vibrating sample magnetometry (VSM). Furthermore, cubic magnetic anisotropy (CMA) measurements are performed. The composition as well as the surface structure have been characterized by in-situ x-ray photoelectron spectroscopy (XPS) and low-energy electron diffraction (LEED), respectively.

One approach of characterizing the magnetic features of CoO and Fe_3O_4/CoO is to evaluate the impact of CoO towards coercivity, remanence, magnetocrystalline anisotropy and especially the exchange bias.

MA 21.21 Tue 9:30 Poster A

Quantum Hall Ferromagnetism in Two-Dimensional Atomic Lattices — Angelika Knothe[1], Thierry Jolicoeur[2], and •Vladimir Fal'ko[1] — [1]National Graphene Institute, The University of Manchester, Manchester M13 9PL, United Kingdom — [2]Laboratoire de Physique Théorique et Modèles Statistiques (LPTMS), Université Paris-Sud, 91405 Orsay, France

Since the seminal discovery of graphene, two-dimensional (2D) atomic crystals have proven to be an exciting playground for investigating novel quantum Hall (QH) phenomena. Besides mono- and bilayer graphene [1,2] this includes 2D surface states of crystals such as the (111) surface of elemental bismuth [3] or heterostructures such as graphene on hexagonal boron nitride [4].

We theoretically investigate these novel QH systems focussing on the multiple discrete degrees of freedom the electrons may carry. Within the framework of QH ferromagnetism, i.e, treating the electronic degrees of freedom as spins and isospins, different aspects of the systems are explored by analysing the resulting spin and isospin structure. Hartree Fock theory is employed to study the influence of electronic interactions in these multicomponent spin and isospin system on the mean field level [5].

[1] A.Knothe, T. Jolicoeur, PRB 92, 165110 (2015), [2] A. Knothe, T. Jolicoeur, PRB 94, 235149 (2016), [3] B. E. Feldman, Ali Yazdani, et al., Science 354, 316-321 (2016) [4] Xi Chen, J. R. Wallbank, V. I. Fal'ko, et al., PRB 89, 075401 (2014) [5] A. Knothe, Ph.D. Thesis, University of Freiburg (2017)

MA 21.22 Tue 9:30 Poster A

Characterization of a synchrotron-based spin-resolved ARPES set-up — •Laura Kugler, Henning Sturmeit, Davide Bossini, Stefano Ponzoni, and Mirko Cinchetti — Experimentelle Physik 6, Technische Universität Dortmund, 44227 Dortmund

Spin-resolved ARPES (angle-resolved photoelectron spectroscopy) is one of the most powerful, yet almost unexplored, method to study the spin properties of metal-organic interfaces. In particular, by analyzing the angular dependence of the spin resolved photoemission yield, it is possible to understand the complex interaction between organic adsorbates and metallic surfaces, and its influence on the spin properties of the interface [1].

In this contribution we will present the characterization of the spin-ARPES set-up at the Beamline 5 at Delta, the synchrotron light source at the Technical University of Dortmund. To characterize the performance of the system, we have performed measurements of the well-known Cu(111) surface and of Co thin films on Cu(100).

[1]M. Cinchetti, A. Dediu, and L. Hueso. Nature Materials 16, 507*515, (2017).

MA 21.23 Tue 9:30 Poster A

First-principles study of the magnetic properties of 4*d*/Fe bilayers on W(001) — •Nanning Petersen, Sebastian Meyer, and Stefan Heinze — Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, Leibnizstrasse 15, 24098 Kiel

The magnetic ground state of an Fe monolayer (ML) can be tuned by growth on different 4*d*- and 5*d*-transition metal substrates due to hybridization at the interface. In particular, it has been shown that an Fe ML on the Pd(001) surface is ferromagnetic while it becomes antiferromagnetic on W(001) [1]. Here, we use density functional theory as implemented in the FLEUR code [2] to investigate the magnetic properties of composite systems of 4*d*/Fe bilayers on the W(001) surface varying the 4*d* transition-metal from Nb to Pd. Since W is a heavy transition-metal with large spin-orbit coupling, significant Dzyaloshinskii-Moriya (DM) interaction is expected. We calculate the energy difference between the ferro- and the antiferromagnetic state for 4*d*/Fe bilayers on W(001). Spin spiral calculations are performed to obtain the exchange and the DM interaction. We first focus on model systems of freestanding 4*d*/Fe/W trilayers as well as the Fe/W bilayer and compare these calculations with those for film systems such as Pd/Fe/W(001).

[1] P. Ferriani *et al.*, Phys. Rev. B **72**, 024452 (2005)
[2] www.flapw.de

MA 21.24 Tue 9:30 Poster A

Realization of a Microstructured Spin-Wave Majority Gate — •Martin Kewenig[1], Thomas Brächer[1], Carsten Dubs[2], Philipp Pirro[1], and Andrii Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]INNOVENT e.V. Technologieentwicklung Jena, 07745 Jena, Germany

Spin-wave logic devices offer large advantages compared to modern CMOS-based elements. For example spin waves promise a significant reduction of Joule heating since they avoid Ohmic losses. An example for such a logic element is the spin-wave majority gate, in which the logical output is given by the majority of the logical inputs. Besides, a spin-wave majority gate is suitable for the construction of all-magnonic circuits. In this contribution, we present the fabrication and investigation of a microstructured spin-wave majority gate device made from a 80 nm thick YIG film. We investigate the operation of the device by means of microwave techniques and performed additional measurements to examine the spin-wave propagation and transmission by using Brillouin light scattering microscopy. This research has been supported by: DFG SFB/TRR 173 Spin+X, Project B01, ERC Starting Grant 678309 MagnonCircuit, and DFG (DU 1427/2-1).

MA 21.25 Tue 9:30 Poster A

Unidirectional excitation and interference of caustic-like spin-wave beams — •Frank Heussner, Matthias Nabinger, Milan Ender, Alexander A. Serga, Burkard Hillebrands, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany

Caustic-like spin-wave beams can be used to steer spin-wave energy in 2D magnetic structures. Hence, they are promising candidates to expedite the development of 2D magnonic logic chips in which interference effects are expected to play an important role for data processing.

Caustic-like beams are formed due to the superposition of different spin-wave modes, which cover a broad range of wavevectors. Consequently, their interference can lead to complex phenomena.

In this work, we present a detailed study of the interference of caustic-like spin-wave beams in 2D magnetic media by utilizing micromagnetic simulations. General laws regarding the control of the observed interference effects are deduced and exemplified. In addition, based on these findings, a method for unidirectional excitation and phase-dependent steering of caustic-like spin-wave beams is revealed. Our results open doors to new possibilities for the technical application of spin waves in 2D microstructures.

Financial support by DFG within project SFB/TRR 173 Spin+X is gratefully acknowledged.

MA 21.26 Tue 9:30 Poster A

Non-reciprocal spin-wave dispersion in a NiFe/Ni bilayer — •Moritz Geilen[1], Morteza Mohseni[1], Thomas Brächer[1], Yves Henry[2], Damien Louis[2], Matthieu Bailleul[2], Florin Ciubotaru[3], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Institut de Physique et Chimie des Matériaux de Strasbourg, UMR 7504, CNRS and Université de Strasbourg, B.P. 43, F-67037 Strasbourg Cedex 2, France — [3]Imec, B-3001 Leuven, Belgium

Surface spin waves have an imaginary wave-vector component $k_\perp$ across the film thickness, which leads to a localization of this mode to one surface of the film and the highly non-reciprocal propagation behaviour. This component is proportional to the in-plane wave-vector component $k_\parallel$, which is perpendicular to the magnetization. But as long as both surfaces of the film are equal and the film itself has homogenous material parameters across its thickness the frequency of spin waves with wave vectors $+k_\parallel$ and $-k_\parallel$ are degenerate. This symmetry is broken in a magnetic bilayer system leading to frequency shift between counter-propagating spin waves.

We present the investigation of the spin wave spectrum of a Ni (25 nm) / NiFe (25 nm) bilayer film employing wave-vector resolved Brillouin light scattering spectroscopy and micromagnetic simulations. We find that the dispersion relation can be manipulated effectively, which is an important property for future magnonic computing devices.

MA 21.27 Tue 9:30 Poster A

Modulation of spin-wave propagation with time-varying magnetic fields — Nana Nishida[1], •Peter Matthies[1,2], Kai Wagner[1,2], Katrin Schultheiss[1], and Helmut Schultheiss[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany

We investigated spin-wave propagation under the influence of nanosecond magnetic field pulses in a 2 μm wide spin-wave waveguide made from NiFe. A coplanar waveguide serves as an antenna for spin waves. The spin wave conduit is magnetized perpendicular to its long axis by an external magnetic field. In order to modulate the amplitude of the internal field, we apply 20 ns long current pulses to a gold conductor that was fabricated below the spin-wave waveguide.

The spin-wave intensity was measured using time-resolved Brillouin light scattering microscopy while applying current pulses with amplitudes that both increase and decrease the effective magnetic field. Depending on the applied microwave frequency, the initial magnetic field and the direction of the pulsed magnetic field different phenomena are observed: First, short spin-wave packets can be created when starting the field sequence off resonance. Second, a pulse induced shift of spin-wave frequencies is detected when starting at resonance, i.e., when propagating spin waves feel a time dependent magnetic field.

MA 21.28 Tue 9:30 Poster A

Injection locking of constriction based Spin-Hall nano-oscillators — •Tillmann Weinhold[1,2], Toni Hache[1,3], Sri Sai Phani Kanth Arekapudi[1,3], Olav Hellwig[1,3], and Helmut Schultheiss[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, Abteilung Magnetismus — [2]Faculty of Physics, Technische Universität Dresden, 01062 Dresden, Germany — [3]Institut für Physik,Technische Universität Chemnitz, D-09107 Chemnitz

Spin-Hall nano-oscillators (SHNOs) are modern auto-oscillation devices. Their simple geometry allows for an optical characterization by Brillouin-Light-Scattering microscopy at room temperature. Here we report on the observation of dc-driven auto-oscillations in constriction based SHNOs under the forcing influence of an added microwave current. We show the possibility of *injection locking* between the applied external signal and the auto-oscillations driven by a direct current. Within the locking range the frequency of the auto-oscillations is forced to the external stimulus. Furthermore, the intensity of the oscillations is strongly increased and the linewidth decreases. Due to the controllability of the auto-oscillations of the magnetization, injection locking can be used to influence the properties of future communication technologies, e.g. based on synchronized constriction based Spin-Hall nano-oscillator arrays.

MA 21.29 Tue 9:30 Poster A

Stokes- /Anti-Stokes signal dependance on polarization in BLS measurements on thin magnetic films — •Tobias Jost, David Breitbach, Thomas Meyer, Moritz Geilen, Burkard Hillebrands, and Philipp Pirro — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany

To investigate magnetoelastic phenomena in thin films, Brillouin light scattering can be used to detect excitations of both the lattice (phonons) and the magnetization (magnons). Depending on the selected plane of polarization of the backscattered light, the signal contains either strong contributions of the phonon- or magnon-signal, respectively or a mixture of both. For a clear distinction of these two signal sources in the analysis of experimental data, one has to know the behavior of either of them separately.
In this work, the Stokes- and Anti-Stokes signals in dependence of the plane of polarization were investigated on a thin permalloy film, in which spin waves were excited by a coplanar wave guide. Contrary to expectations the magnon-signal did not drop to zero for any plane of polarization which indicates that the backscattered photons are not completely linear polarized. In addition the Stokes- and Anti-stokes amplitudes did not reach their respective maximum and minimum at the same polarization configuration.

MA 21.30 Tue 9:30 Poster A

Backscattering-Immune Spin-Wave Modes for Protected Magnon Transport — •Morteza Mohseni, Qi Wang, Burkard Hillebrands, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany.

Protected transport of energy and particles has been an intensive subject of research during the last decade. It has stimulated a lot of interest in the field of topological insulators. The idea of protected transport transferred into the realm of magnonics by considering different types of magnonic crystals. Indeed, protected magnon transport would constitute a major breakthrough in reducing the losses, which are associated with, e.g., defects and inhomogeneities in magnonic networks for data processing. Here, we show that in homogeneous magnetic thin films, backscattering-immune spin-wave modes exist. Using micromagnetic simulations, we show that in an in-plane magnetized film with relatively small thickness, non-reciprocal waves which propagate perpendicular to the static magnetization can be robust against even large inhomogeneities and defects. Such robust and non-reciprocal spin waves open the possibility for designing highly efficient magnonic elements. In addition, their strong protection should stimulate further investigation of the topology of those waves.

MA 21.31 Tue 9:30 Poster A

Spin-Wave Reciprocity in the Presence of Néel Walls — •Lukas Körber, Kai Wagner, Attila Kákay, and Helmut Schultheiss — Helmholtz-Zentrum Dresden - Rossendorf, Bautzner Landstraße 400, 01328 Dresden, Germany

We report on the reciprocity of channeled spin waves in a 180° Néel wall with special focus on the in-plane curling of the magnetization. In particular, the dispersion relation, phase fronts and frequency-dependent spin-wave intensites where studied by means of micromagnetic simulations. Despite the strong curling of the magnetization at the center of the Néel wall, non-reciprocity is only found in the domains whereas the wall acts as a reciprocal channel.

Corresponding paper: L. Körber, K. Wagner, A. Kákay, H. Schultheiss "Spin-wave reciprocity in the presence of Néel walls" IEEE Magnetic Letters PP, 99 (2017), DOI: 10.1109/LMAG.2017.2762642

MA 21.32 Tue 9:30 Poster A

Investigation of spin wave modes in laterally confined Yttrium-Iron-Garnet (YIG) thin films — •Philipp Geyer, Maximilian Paleschke, Philip Trempler, and Georg Schmidt — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle(Saale)

Magnonics is promising for the realization of low power information storage and processing, by excitation of the spin lattice rather than by moving electrons. In confined structures the propagation and damping of spin waves strongly depends on the geometry. For example shape anisotropy fields can change the dispersion in different directions. Different geometries thus lead to fundamentally different resonance characteristics. In contrast to a rather complicated analytical description for example by using Green functions theory, micromagnetic simulations provide an easy way to examine different structures theoretically. We have performed micromagnetic simulations of magnetic nanostructures with mumax3 [1] which we can compare to experimental results. For the experiments arrays of identical nanostructures were investigated by ferromagnetic resonance. The structures were fabricated from thin YIG films with very low damping [2]. The results show numerous standing spin wave modes including edge modes. Besides rectangular shapes also other geometries like triangles were successfully investigated.

[1] "The design and verification of mumax3", AIP Advances 4, 107133 (2014)
[2] C. Hauser et. al., Scientific Reports 6, 20827 (2016)

MA 21.33 Tue 9:30 Poster A

On-chip magnetic field bias for magnon-resonator experiments — •Stefan Eisele[1], Tomislav Piskor[1], Marco Pfirrmann[1], Andre Schneider[1], Hannes Rotzinger[1], Alexey V. Ustinov[1,3], and Martin Weides[1,2] — [1]Karlsruhe Institute of Technology, Germany — [2]Johannes Gutenberg University Mainz, Germany — [3]Russian Quantum Center, Moscow, Russia

Today, spin waves are considered as promising candidates for classical and quantum information processing. Their propagation properties are conventionally controlled through an external magnetic field bias to the ferromagnetic materials, generally generated by coils or permanent magnets. The high inductances of coils make manipulations on a short timescale impossible. Furthermore, the unconfined magnetic fields require shielding to avoid cross-bias of neighboring magnonic cells. In this work, we develop an on-chip magnetic field bias to overcome these constraints. For application in a cryogenic environment, i.e., in liquid helium at 4.2 K, very low heat dissipation is mandatory. Our system consists of a superconducting niobium feedline with a magnetic film deposited on top. The magnetic bias field is provided by the superconducting current. For on-chip ferromagnetic resonance measurements, an additional niobium feedline is added on top of the magnetic structure. Due to the small inductance of the biasing component, current variations on short timescales are achievable. This work enables combining novel compact magnonic circuits with electrical quantum circuits to process microwave signals in cryogenic environments.

MA 21.34 Tue 9:30 Poster A

Controlling the phase in coupled magnon-photonic circuits — •Christine Dörflinger[1], Isabella Boventer[1,2], Marco Pfirrmann[1], Tomislav Piskor[1], Alexey Ustinov[1], Mathias Kläui[2], and Martin Weides[1,2] — [1]Karlsruhe Institute of Technology, Physikalisches Institut, Karlsruhe, Germany — [2]Johannes-Gutenberg University, Institute of Physics, Mainz, Germany

Polaritons are quasiparticles describing hybridized states resulting from light-matter interactions. They offer new perspectives for applications in information processing technology. In this work, we focus on magnon-photon-polaritons (MPPs) describing electromagnetic coupling between collective spin excitations of a magnetically ordered material and photons. Our interest is to study the MPP's anticrossing spectrum when such a system features a relative phase shift between a resonator mode and the uniform spin precession of the Kittel mode. Experimentally, we introduce an additional drive of adjustable phase compared to standard experiments. Therefore we utilize a sandwich design consisting of a lambda/2 microwave resonator, a YIG film and a microstrip line. Both the resonator and the middle segment of the microstrip line are aligned parallel to an external static magnetic field and are driven by the same source but variably shifted in phase. With this setup we aim to measure the phase dependency of the transmission and reflection spectra and discuss the influences on the MPP line shape. Tuning the anticrossing gap could offer new possibilities for applications such as amplifiers and interferometers.

MA 21.35 Tue 9:30 Poster A

Magnon Bandstructure of strongly dipolar-coupled nanoparticle chains — •Benjamin Zingsem[1,2], Thomas Feggeler[1], Alexandra Terwey[1], Sara Ghaisari[3], Detlef Spoddig[2], Damien Faivre[3], Ralf Meckenstock[1], Michael Farle[1], and Michael Winklhofer[4] — [1]Faculty of Physics, University of Duisburg-Essen, 47057 Duisburg, Germany. — [2]Ernst Ruska Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [3]Department of Biomaterials, Max Planck Institute of Colloids and Interfaces, Potsdam, Germany — [4]School of Mathematics and Science, University of Oldenburg, 26129 Oldenburg, Germany.

We present Ferromagnetic Resonance (FMR) spectroscopy on individual chains of magnetic nanoparticles. The chains consist of 10-20 magnetite crystals with a crystal size of about 30 nm. Our measurements reveal intriguing properties regarding the formation of magnonic band gaps, as well as an unusual curvature of angular dependent resonance lines. We show that through modification of the geometric arrangement of these particles, i.e. by introducing defects or kinks, the magnonic properties of these chains can be tailored, yielding potential applications for nano-sized magnon-logic and spintronic devices. In addition to the measurements, we performed high performance GPU accelerated micromagnetic simulations, which provide further insight into the unusual magnon band structure. These simulations are in good agreement with the measured spectra and allow us to identify the connection between spatial and spectral features.

MA 21.36 Tue 9:30 Poster A

Design of a spin-wave flat lens — •Mateusz Zelent[1], Paweł Gruszecki[1], Marina Mailian[2], Oksana Gorobets[2], Yuri Gorobets[2,3], Maciej Krawczyk[1], and Vishal Vashista[1] — [1]Faculty of Physics, Adam Mickiewicz University in Poznan, Umultowska 85, Poznan, 61-614, Poland — [2]Faculty of Physics and Mathematics, National Technical University of Ukraine *Igor Sikorsky Kyiv Polytechnic Institute*, 37 Peremogy Avenue, Kyiv, 03056, Ukraine — [3]Institute of Magnetism, National Academy of Sciences of Ukraine, 36-b Vernadskogo Street, Kyiv, 03142, Ukraine

The focusing of plane spin waves propagating in a thin ferromagnetic film by designed phase-shift on a metasurface formed by the ultranarrow interface was studied. We demonstrated with micromagnetic simulations and analytical model, that the effect exists for the exchange spin waves propagating in thin Co film in transmission through the interface, where interlayer exchange interactions are present. The phase shift of transmitted spin waves is achieved by introducing ultrathin nonmagnetic metallic spacer, with a width much smaller than the spin wave wavelength. Due to RKKY interaction, the change of the metal width allows to modify interfacial exchange coupling, which determine the phase of the transmitted spin waves. We combine this phase-shift dependency along the interface with the lens equation to design a spin wave flat lens based on magnonic matasurface. Funded from the EU Horizon 2020, G.A. No. 644348.sign a spin wave flat lens based on magnonic matasurface.

MA 21.37 Tue 9:30 Poster A

Spin Wave Propagation in Thin Films with Perpendicular Magnetic Anisotropy — •Matías Grassi[1], Yves Henry[1], Michel Hehn[2], Thibaut Devolder[3], and Matthieu Bailleul[1] — [1]Institut de Physique et Chimie des Matériaux de Strasbourg, — CNRS, Université de Strasbourg, B.P. 43, 67034 Strasbourg Cedex 2, France. — [2]Institut Jean Lamour, CNRS, Université de Lorraine, B.P. 70239, F-54506 Vandoeuvre-lès-Nancy Cedex, France — [3]Centre de Nanosciences et de Nanotechnologies, CNRS, Univ. Paris-Sud, Université Paris-Saclay, C2N-Orsay, 91405 Orsay Cedex, France.

We present a study of the spin wave (SW) dynamics in thin films with perpendicular magnetic anisotropy. The interactions between the SW and different magnetic textures were studied by a dynamic matrix approach using a custom developed code [1]. In particular, we analyze the spin wave propagation in samples with a stripe domain structure and its dependence as function of the applied magnetic field. We focus on two particular questions: how the evolution of spin wave dispersions in the saturated state could explain the formation of the stripes domains; and how the domain walls within the stripe structure can be used as waveguides for SW —the so-called Domain Wall Channeled Spin Waves (DWCSW). These simulations are used to design Propagating Spin Wave Spectroscopy experiments, allowing one to measure the SW frequencies within a determined wave length range.

[1] Y. Henry, O. Gladii and M. Bailleul, https://arxiv.org/abs/1611.06153

MA 21.38 Tue 9:30 Poster A

Nano-scaled magnon transistor based on three-magnon splitting — •Qi Wang, Philipp Pirro, Thomas Brächer, and Andrii Chumak — Fachbereich Physik, Technische Universitaet Kaiserslautern, Kaiserslautern, Germany.

Spin waves and their quanta magnons open up a promising branch of high-speed and low-power information processing. The realization of single-chip all-magnon information systems demands for the development of circuits in which magnon currents can be manipulated by magnons themselves. In our previous study, we presented and tested experimentally a proof-of-concept magnon transistor. Here we use micromagnetic simulations to propose a conceptually different approach for the realization of a nano-scaled magnon transistor. In this device, a three- rather than a four-magnon scattering process is utilized. Source magnons interact with the gate magnons boosting a three-magnon scattering process in which one gate magnon scatters into one new source magnon and into one idle magnon. As a result, the number of the source magnons at the drain is increased and the transistor acts as an amplifier of magnon signals. Financial support by the ERC Starting Grant "MagnonCircuits" is gratefully acknowledged.

MA 21.39 Tue 9:30 Poster A

Spin Wave Propagation in Thin Films with Perpendicular Magnetic Anisotropy — •Matías Grassi, Yves Henry, and Matthieu Bailleul — Institut de Physique et Chimie des Matériaux de Strasbourg, CNRS, Université de Strasbourg, B.P. 43, 67034 Strasbourg Cedex 2, France.

We present a study of the spin wave (SW) dynamics in thin films with perpendicular magnetic anisotropy. The interactions between the SW and different magnetic textures were studied by a dynamic matrix approach using a custom developed code [1]. In particular, we analyze the spin wave propagation in samples with a stripe domain structure and its dependence as function of the applied magnetic field. We focus on two particular questions: how the evolution of spin wave dispersions in the saturated state could explain the formation of the stripes domains; and how the domain walls within the stripe structure can be used as waveguides for SW —the so-called Domain Wall Channeled Spin Waves (DWCSW)[2]. These simulations are used to design Propagating Spin Wave Spectroscopy experiments, allowing one to measure the SW frequencies within a determined wave length range.

[1] Y. Henry, O. Gladii and M. Bailleul, https://arxiv.org/abs/1611.06153
[2] SWANGATE ANR-16-CE24-0027-01

MA 21.40 Tue 9:30 Poster A

Propagating spin waves spectroscopy of YIG magnonic crystal — •Hugo Merbouche, Martin Collet, Lucile Soumah, Paolo Bortolotti, Vincent Cros, and Abdelmadjid Anane — Unité Mixte de Physique, CNRS, Thales, Univ. Paris-Sud, Université Paris-Saclay, 91767 Palaiseau, France

The propagation of Damon-Eshbach spin waves in a magnonic crystal (MC) is studied. The MC consists of periodically nanostructured waveguides (WGs) made out of 20 nm thick YIG film. We observe a 25MHz transmission gap at 1.3GHz. Fifty parallel 2.5μm wide WGs are designed, using laser lithography. Two gold antennas are deposited on top, 30μm apart. Using electron beam lithography and dry ion etching, 150nm wide grooves, orthogonal to the WGs principal axis, are etched. The period corresponds to a Bragg k-vector of $1\mu m^{-1}$ and the depth is incremented from 0 to 20nm in 6 steps.

The propagation properties are then measured using a VNA based all-inductive method: Propagating Spin Wave Spectroscopy (PSWS). For un-etched WGs, a good agreement with theoretical expectations is observed. For MCs with grooves depth greater than 5nm, a 25MHz transmission gap at 1.3GHz is measured, corresponding to a decrease by a factor 2.4 of the output signal. Transmission outside the frequency gap is unaffected by the grooves till a depth of about 10nm. Nevertheless, the signal remains strong even when the YIG film becomes discontinuous.

MA 21.41 Tue 9:30 Poster A

Phase-modulated Fresnel zone plate for spin waves in bulk and thin-film geometry — •Piotr Graczyk[1], Irina Tukavkina[2], Mateusz Zelent[1], Oksana Gorobets[2,3], and Maciej Krawczyk[1] — [1]Faculty of Physics, Adam Mickiewicz University in Poznan, Umultowska 85, 61-614 Poznan, Poland — [2]National Technical University of Ukraine, "Igor Sikorsky Kyiv Polytechnic Institute", 37 Peremogy Ave., 03056, Kyiv, Ukraine — [3]Institute of Magnetism, National Academy of Sciences of Ukraine, 36-b Vernadskogost., 03142, Kyiv, Ukraine

We present results of investigation on the metasurface designed to effectively focus spin wave by means of diffraction. The boundary conditions [1] for the interlattice exchange and surface anisotropy were introduced at the interface of two ferromagnetic media to form phase-modulated Fresnel zone plate. The problem was treated analytically and supported by the numerical simulations. We extended the investigation to the case of the interface in a thin-film geometry with dipolar interactions included. It is shown, that proper tuning of the anisotropy at the interface keeps the tramsmittivity at a high level while the exchange between adjacent materials is weak, leding to the significant phase shift. We keep parameters of our model close to the realistic values, providing a way for experimental realization.

[1] V.V. Kruglyak, O.Y. Gorobets, Y.I. Gorobets, and A.N. Kuchko, J. Phys. Condens. Matter 26, 406001 (2014).

Financial support from the EU*s Horizon 2020 research and innovation programme under Marie Sklodowska-Curie GA No.644348 (MagIC)

MA 21.42 Tue 9:30 Poster A

Electronic transport through a one dimensional vacuum barrier using Greens functions — •Max Götzler, Michael Czerner, and Christian Heiliger — Institut für theoretische Physik, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen

We study the electronic transport through a one dimensional vacuum barrier, using a tight-binding approximation and the method of Greens funtions for solving the Schrödinger equation. We calculate the transmission function and electron density in the equilibrium case. We then solve the poisson equation for the non interacting charge distribution and try to self-consistently calculate the new charge distribution with respect to electrostatic interactions. This is repeated for small applied voltages, using a steady state Keldysh-formalism. We calculate the current and the new electron density, then compare the results to the equilibrium case.

MA 21.43 Tue 9:30 Poster A

Ultrafast magnetization and spin dynamics driven by terahertz radiation pulses — •Julius Heitz[1], Lukáš Nádvorník[1], Tom Seifert[1], Martin Wolf[2], and Tobias Kampfrath[1,2] — [1]Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Fritz-Haber-Institut der Max Planck Gesellschaft, Faradayweg 4-6, 14195 Berli

Magnetization reversal, spin transfer torque, giant magnetoresistance [1] and the emission of terahertz (THz) radiation [2] are intriguing spintronic applications, each of which relies on well-controlled generation and manipulation of spin currents. The established methods to generate spin currents are the anomalous and spin Hall effects (AHE, SHE), whose inverse were demonstrated recently up to THz frequencies [3]. This makes them excellent candidates to extend the bandwidth of spin information processing into the THz range. However, so far no direct observation of AHE-related ultrafast spin accumulation at sample interfaces has been reported.

In this contribution, we study the interaction of ultrashort intense

THz pulses with magnetic thin films. In our experiment, the strong THz electric field (up to ~0.5 MV/cm) is used to drive ultrafast charge currents in the plane of the structure. By using the magnetooptic Kerr effect, we investigate how such excitation and the AHE currents can lead to ultrafast spin and charge redistribution in thin films.

1. C. Chappert, A. Fert, Frédéric Nguyen Van Dau, Nature Materials 6, 813-823 (2007) 2. T. Kampfrath et al., Nature Nanotech. 8, 256 (2013). 3. T. Seifert, M. Wolf, T. Kampfrath et al., Nature Photon. 10, 483 (2016).

MA 21.44 Tue 9:30 Poster A

Terahertz Spin Currents and Spin Hall Effect in β-Tungsten and Au_xPt_{1-x} Alloys — •Oliver Gueckstock[1], Mohammadreza Rouzegar[1], Tom Seifert[1], Sebastian Dapper[2], Satya Prakash Bommanaboyena[2], Björn Gliniors[2], Lukas Liensberger[3], Martin Wolf[1], Mathias Weiler[3], Markus Meinert[2], and Tobias Kampfrath[1,4] — [1]FHI der MPG, Berlin — [2]U Bielefeld, Bielefeld — [3]WMI, Garching — [4]FU Berlin, Berlin

The efficient conversion of spin into charge currents by spin-orbit interaction (SOI) will be important for future spin-based electronics [1]. Recently, much effort has been devoted to the identification of new large-SOI materials. One promising material is β-tungsten, for which large spin Hall angles (SHA) have been reported [2]. In our experiments, we employ femtosecond optical pulses to trigger ultrafast spin transport in magnetic thin-film stacks. Due to SOI, this spin current is partially converted into a transverse charge current which is monitored by detecting the concomitantly emitted THz electromagnetic radiation [3,4]. In particular, we study THz emission from bilayers of cobalt-iron-boron (CoFeB) and β-tungsten with varying oxygen concentration and bilayers of CoFeB and Au_xPt_{1-x} alloys. By additionally measuring the THz conductivity of these films, we can separate the influence of the spin Hall conductivity and the longitudinal conductivity to the SHA.

References: [1] S.A. Wolf et al., Science 294.5546 (2001), [2] K. Demasius et al., Nature Comm. 7, 10644 (2016), [3] T. Kampfrath et al., Nature Nanotech. 8, 256 (2013), [4] T. Seifert et al., Nature Phot. 10, 483 (2016)

MA 21.45 Tue 9:30 Poster A

Launching magnons at the terahertz speed of the spin Seebeck effect — Tom Seifert[1,2], Joel Cramer[3], Joe Barker[4], Samridh Jaiswal[3], Gerhard Jakob[3], Martin Wolf[2], Georg Woltersdorf[5], Piet W. Brouwer[1], Mathias Kläui[3], and •Tobias Kampfrath[1,2] — [1]FU Berlin — [2]FHI Berlin — [3]JGU Mainz — [4]Tohoku University, Japan — [5]MLU Halle

We study the initial steps of the spin Seebeck effect with 10 fs time resolution in prototypical bilayers of the ferrimagnet yttrium iron garnet and platinum. Following excitation of the metal with an ultrashort laser pulse, the spin Seebeck current j_s is measured all-optically using the inverse spin Hall effect and terahertz electrooptic sampling. The current rises on the $\sim$ 200 fs time scale on which the electrons in the metal approach a Fermi-Dirac distribution. This observation is a hallmark of the assumption that the spin transfer arises from conduction electrons scattering off the magnetic interface. Model-supported analysis shows that j_s follows the dynamics of the metal electrons quasi-instantaneously because their spins have a correlation time of only $\sim$ 4 fs and deflect the ferrimagnetic moments without inertia. Promising applications for material characterization, interface probing, spin-noise detection and terahertz spin pumping come into reach.

MA 21.46 Tue 9:30 Poster A

Terahertz writing of an antiferromagnetic memory — •Tom Seifert[1], Kamil Olejník[2], Tomas Jungwirth[2,3], and Tobias Kampfrath[1] — [1]Fritz Haber Institut der MPG, Berlin, Germany — [2]Academy of Sciences of the Czech Republic, Prague, Czech Republic — [3]University of Nottingham, Nottingham, United Kingdom

The electrical switching of the magnetic order of antiferromagnets (AFMs) using Néel spin-orbit torques (NSOT) paved the way for AFM-based memory applications [1]. Importantly, in AFMs the frequencies of long-wavelength magnons are strongly enhanced by the exchange interaction opening up the potential for terahertz (THz) switching speeds [2]. Previous studies showed the feasibility of electrical writing of AMFs with pulse lengths from milliseconds to hundreds of picoseconds [3].

Here, we further reduce the current duration down to the picosecond time scale employing an all-optical writing scheme based on free-space THz pulses. With these picosecond laser pulses [4], we observe the analogous switching phenomenology of epitaxial CuMnAs films as with millisecond and nanosecond current pulses. Our results suggest that the current-induced NSOT switching mechanism for AFMs is also operative in the THz range.

The presented results were obtained in close collaboration with the groups of R.P. Campion, P. Gambardella, P. Kuzel, P. Nemec, J. Sinova and J. Wunderlich.

[1] P. Wadley et al., *Science* **351** (2016). [2] T. Kampfrath et al., *Nat. Phot.* **5** (2011). [3] K. Olejník et al., *Nat. Commun.* **8** (2017). [4] K. Olejník et al., arXiv:1711.08444 (2017).

MA 21.47 Tue 9:30 Poster A

Spin to charge current conversion in transition metal dichalcogenide — •Lukáš Nádvorník[1], Lukas Braun[2], Bin Cui[3], Tom Seifert[1], Oliver Glückstock[2], Martin Wolf[2], Stuart Parkin[3], and Tobias Kampfrath[1,2] — [1]Freie Universität, Berlin, Germany — [2]Fritz-Haber-Institut der MPG, Berlin, Germany — [3]Max Planck Institute of Microstructure Physics, Halle, Germany

In the last decade, transition metal dichalcogenides (TMDCs) have attracted considerable attention for their unique mechanical, electronic and spin properties [1]. By sharing a similar honeycomb crystal structure with graphene, they allow for optical generation of the valley polarization. Unlike graphene, they also exhibit a large spin-orbit coupling. This feature and the recently observed valley Hall effect [2] makes TMDCs ideal candidates for spintronic and valleytronic applications.

In this contribution, we report on the observation of an ultrafast injection of in-plane-polarized electron spins and the inverse spin Hall effect (iSHE) in metallic TMDC NbSe2 at terahertz (THz) frequencies. By excitation of an adjacent ferromagnetic layer by an ultrashort optical pulse, we launch a spin-polarized current into the TMDC where it is converted to a charge current via the iSHE. This ultrashort charge current burst acts as a source of an ultrashort THz electromagnetic pulse [3] whose measurement allows us to estimate the efficiency and dynamics of the spin-to-charge-current conversion.

[1] S. Manzeli et al., Nature Reviews 2, 17033 (2017). [2] K.F. Mak et al., Science 344, 1489 (2014). [3] T. Kampfrath et al., Nature Nanotech. 8, 256 (2013).

MA 21.48 Tue 9:30 Poster A

Determining the spotsize of a microlense to build a THz emitter — •Nina Meyer[1], Finn Lietzow[1], Jakob Walowski[1], Christian Denker[1], Tom Seifert[2], Tobias Kampfrath[2], and Markus Münzenberg[1] — [1]Institute of Physics, Greifswald University, Greifswald, Germany — [2]Fritz Haber Institut, MPG, Berlin, Germany

So far Terahertz (THz) spectroscopy has been used as a characterization method, since the intermolecular bonding energies of larger molecules (4 to 400 meV) are in the THz range (1 to 100 THz). The excitation energy for phonons or plasmons in solids lies in the same range. Therefore, THz radiation can be used for probing and driving such low-energy excitations. To lower costs and to simplify analysis smaller THz emitters and detectors are needed. Here we present our first attempts towards micrometer sized spintronic THz emitters. We start with fabricating microlenses on glass substrates using 3D 2-photon-lithography. By this we were able to focus a 1560 nm laser beam with 100 fs pulselength on a CMOS Chip. We measured a spotsize smaller than 10 μm at the focus length for a microlens with a radius of 300 μm. We also fabricated microlenses on a fiber to guide the laser beam directly onto the microlens. The next step is to use the microlens on a fiber to generate THz radiation. To accomplish this, we are going to include a thin film of a ferromagnetic layer and a non-magnetic cap layer. By focusing a femtosecond laser pulse onto the thin film THz radiation is generated. For large scales, this approach has been demonstrated by Seifert et al. [1].

[1] T. Seifert et al., Nat. Photon. 10 (2016) 483.

MA 21.49 Tue 9:30 Poster A

Spintronic terahertz emitters based on epitaxially grown Fe/Pt, Ta/Fe, Ta/Fe/Pt multilayers — •Laura Scheuer[1], Garik Torosyan[2], Sascha Keller[1], René Beigang[1], and Evangelos Th. Papaioannou[1] — [1]TU Kaiserslautern, Fachbereich Physik and Landesforschungszentrum OPTIMAS, Germany — [2]Photonic Center Kaiserslautern, Germany

We demonstrate the efficient generation of pulsed broadband terahertz radiation utilizing the inverse spin Hall effect in Fe/Pt, Ta/Fe and Ta/Fe/Pt multilayers grown epitaxially on MgO and sapphire substrates. The emitter was optimized with respect to layer thickness, growth parameters, substrates and geometrical arrangement [1]. The experimentally determined optimum layer thicknesses were in qualitative agreement with simulations of the spin current induced in the ferromagnetic layer. Our model takes into account generation of spin polarization, spin diffusion and accumulation in Fe and Ta, Pt and electrical as well as optical properties of the bilayer samples. The general performance makes the spintronic terahertz emitters compatible with established emitters based on optical rectification in nonlinear crystals.

[1] G. Torosyan et al., arxiv.org/abs/1707.08894 (2017)

MA 21.50 Tue 9:30 Poster A

Implementation of a self-consistent NEQ scheme in the KKR formalism — •Alexander Fabian, Michael Czerner, and Christian Heiliger — Institut für theoretische Physik, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen

Todays need for even more efficient and faster nano sized devices requires a decent understanding of the behavior of nanostructured materials under applied fields. However, most common approaches rely on the equilibrium properties of the material and use approximations to describe the non-equilibrium behavior. Since crucial assumptions have to be made, these descriptions do not always describe all of the properties correctly and one needs an exact description to calculate non-equilibrium properties. The Keldysh formalism can be used to describe the non-equilibirum properties within the framework of an ab initio theory. We implemented a self-consistent scheme in our multi-scattering DFT code based on the KKR method. To calculate non-equilibrium properties, we use a steady state Keldysh formalism with non-equilibrium Green's functions. The electronic density is calculated by splitting the energy contour in two parts according to the applied voltage. In the first part, the density is calculated with equilibrium tools while the second part is calculated with the actual Keldysh formalism. Summing the two parts the resulting density is used to solve the system self-consistently in the non-equilibrium steady state. Charge displacement due to the applied voltage and the behavior of the voltage in the underlying system are extracted from the self-consistent values.

MA 21.51 Tue 9:30 Poster A

Insights into spin and anomalous Hall effect induced charge and spin currents through ferromagnetic/nonmagnetic interfaces — •Albert Hönemann[1], Christian Herschbach[1], Martin Gradhand[2], and Ingrid Mertig[1,3] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]University of Bristol, Bristol, United Kingdom — [3]Max Planck Institute of Microstructure Physics, Halle, Germany

Transport phenomena caused by spin-orbit coupling such as spin Hall effect (SHE) [1] and anomalous Hall effect (AHE) [2] are highly relevant topics of current research. In ferromagnetic/nonmagnetic heterostructures the interplay of spin-orbit and exchange interaction enables new phenomena as for example spin-orbit torques [3].

We use an *ab initio* approach, a relativistic Korringa-Kohn-Rostoker method, [4] and solve the linearized Boltzmann equation to describe the electronic transport [5]. We investigate the AHE-induced charge current as well as the SHE-induced spin current perpendicular to the interface in a Co/Cu superlattice alloyed with Bi. We are particularly interested in the spatial distribution of charge and spin current with respect to the interface. The presented results help to understand the underlying microscopic mechanism of charge and spin transport through interfaces.

[1] Sinova *et al.*, Rev. Mod. Phys. **87**, 1213 (2015); [2] Nagaosa *et al.*, Rev. Mod. Phys. **82**, 1539 (2010); [3] Gambardella *et al.*, Phil. Trans. R. Soc. A (2011) **369**, 3175-3197; [4] Gradhand *et al.*, PRB **80**, 224413 (2009); [5] Gradhand *et al.*, PRL **104**, 186403 (2010);

MA 21.52 Tue 9:30 Poster A

Non-local magnetoresistance in normal metal|yttrium iron garnet heterostructures — •Birte Cöster, Matthias Althammer, Tobias Wimmer, Stephan Geprägs, Hans Huebl, and Rudolf Gross — Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany

Pure spin currents, i.e. the flow of angular momentum without an accompanying charge current, represent a new paradigm in state-of-the-art spintronics. In conventional electrical conductors pure spin currents are transported via mobile charge carriers. In contrast, in a magnetically ordered insulator pure spin currents are based on the flow of quantized excitations of the spin structure. Normal metal (NM)/ferromagnetic insulator (FMI) heterostructures allow to study pure spin current transport by utilizing the direct and inverse spin Hall effect in the normal metal.

In our experiments, we investigate NM/FMI heterostructures using YIG as FMI. For the NM layer we use different materials, which are deposited via UHV sputtering technique. We employ nanolithography to pattern NM stripe structures on the LPE-YIG thin films grown on GGG substrates. In the non-local magnetotransport experiments, we apply a charge current through one strip while measuring the resulting electrical potential difference of an adjacent strip. We discuss the results obtained for different NM materials and deposition conditions. Moreover, the comparison of the different materials allows us to extract the relevant pure spin current transport properties.

Financial support via NIM is gratefully acknowledged.

MA 21.53 Tue 9:30 Poster A

Ab initio calculations of magneto crystalline anisotropy in magnetic tunnel junctions — •Philipp Risius, Carsten Mahr, Michael Czerner, and Christian Heiliger — Institut für Theoretische Physik, Universität Gießen, Germany

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

MA 21.54 Tue 9:30 Poster A

Non-local magnon transport in ferrimagnetic insulators — •Tobias Wimmer[1,2], Kathrin Ganzhorn[1,2], Stefan Klingler[1,2], Nynke Vlietstra[1,2], Stephan Gepraegs[1], Rudolf Gross[1,2,3], Hans Huebl[1,2,3], and Sebastian T. B. Goennenwein[1,2,3,4] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Nanosystems Initiative Munich (NIM), Schellingstraße 4, München, Germany — [4]Institut für Festkörperphysik, Technische Universität Dresden, Dresden, Germany

Pure spin currents are the key ingredient for information processing in spintronic devices. Recent experiments in ferromagnetic insulator (FMI)/Pt heterostructures show that information can be carried by diffusing thermal magnons in Yttrium-Iron-Garnet (YIG) as well as Gadolinium-Iron-Garnet (GdIG). These non-equilibrium magnons are generated electrically at the FMI|Pt interface using a dc charge current and are detected as a non-local voltage signal in a second electrically isolated Pt strip. Here, we study this so-called magnon-mediated magnetoresistance (MMR) in detail as a function of the injector and detector separation, temperature and magnetic field. Based on our findings, we have implemented a magnonic majority gate consisting of a 4-strip YIG|Pt device. We furthermore present the MMR effect in the compensated ferrimagnet GdIG, offering intriguing insights into the transport behavior of different magnon branches.

MA 21.55 Tue 9:30 Poster A

Current induced Néel-order switching in magnetron sputtered antiferromagnetic Mn_2Au — •Dominik Graulich and Markus Meinert — Center for Spineletronic Materials and Devices, Bielefeld University, Germany

Antiferromagnets which fulfill certain symmetry properties allow for an intrinsic relativistic Nèel-order spin-orbit torque (NSOT) driven by an electrical current [1]. In tetragonal Mn_2Au the two antiferromagnetically coupled sublattices are inversion partners and therefore experience a staggered spin orbit field caused by the inverse spin galvanic effect (iSGE) resulting in a NSOT, which can reorient the Nèel vector **L** perpendicular to the applied charge current [2]. Applying the current in two orthogonal directions and readout of the two states by the planar Hall effect (PHE) or anisotropic magnetoresistance (AMR) could allow for manufacturing novel antiferromagnetic memory devices that are extraordinarily robust against external magnetic influences [3] with the state of **L** being long-term stable at room temperature [4]. Here, we report on our experiments on the electrical switching of **L** using short current pulses in expitaxial grown, magnetron sputtered Mn_2Au. Our findings support the hypothesis of a thermally activated switching process [4].

[1] J. Železný et al., Phys. Rev. Lett. **113**, 157201 (2014)
[2] P. Wadley et al., Science **351** 587 (2016)
[3] T. Jungwirth et al., Nat. Nanotechn. **11** 231 (2016)
[4] M. Meinert et al. arxiv.org/abs/1706.06983 (2017)

MA 21.56 Tue 9:30 Poster A

Particle-in-Cell Model for Electronic Transport in Metallic Heterostructures — •Marius Weber, Dennis Michael Nenno, and Hans Christian Schneider — University of Kaiserslautern, Kaiserslautern, Germany

Ultrafast demagnetization dynamics triggered by ultrashort laser excitation can be influenced decisively by hot carrier transport in ferromagnet-metal heterostructures [1]. Motivated by recent experiments [2,3], we investigate the transport behavior of excited electrons in Gold. In our model, the electronic dynamics of "hot" electrons is described using the Boltzmann Transport Equation (BTE) and includes the generation of secondary electrons by scattering processes. We use a particle-in-cell (PIC) approach to solve the BTE and calculate the diffusion coefficient. We demonstrate that this approach reproduces the generalized diffusion coefficient as found in Ref. [4] and study the electronic dynamics in a single metal layer in detail. We also show that interfaces in metallic sandwich structures can play a crucial role in electronic spin transport.

[1] D. Rudolf et al., Nature Communications 3, 1037 (2012)
[2] A. Melnikov et al., Physical Review Letters 107, 076601 (2011).
[3] N. Bergeard et al., Physical Review Letters 117, 147203 (2016).
[4] M. Battiato, K. Carva, and P. M. Oppeneer, Physical Review B 86, 024404 (2012).

MA 21.57 Tue 9:30 Poster A

Structural characterization of hexagonal Mn_3X (X = Ga, Ge, Sn) thin films — •Philipp Zilske[1], Jungwoo Koo[1], Samer Kurdi[2], and Günter Reiss[1] — [1]Center for Spinelectronic Materials and Devices, Bielefeld University, Germany — [2]Department of Materials Science and Metallurgy, University of Cambridge, United Kingdom

In the last decade, antiferromagnetic spintronics has established as an important field for future magnetic storage devices [1]. Recently, non-collinear antiferromagnets received much attention due to their promising electronic properties. Theoretical calculations as well as first experimental results show large anomalous Hall effect for hexagonal non-collinear antiferromagnets Mn_3X (X = Ga, Ge, Sn). However, such properties are only studied for single crystalline bulk samples [2-4].

Here, we report on the structural analysis of Mn_3X (X = Ga, Ge, Sn) thin films. Epitaxial Mn_3X films were grown via magnetron co-sputtering. The dependence of the crystalline quality on the deposition temperature and the stoichiometry, as well as the influence of the buffer layer was investigated by X-ray diffraction measurements.

Furthermore, we discuss the transport properties of several samples.

[1] T. Jungwirth *et al.*, Nature Nanotech. **11**, 231 (2016)
[2] Y. Zhang *et al.*, Phys. Rev. B **95**, 075128 (2017)
[3] S. Nakatsuji *et al.*, Nature **527**, 212 (2015)
[4] N. Kiyohara *et al.*, Phys. Rev. Appl. **5**, 064009 (2016)

MA 21.58 Tue 9:30 Poster A

Effect of interlayer insertion on the spin pumping properties in $Co_{40}Fe_{40}B_{20}$/X/Pt,Ta heterostructures — •Matthias Schweizer, Andrés Conca, Sascha Keller, Evangelos Papaioannou, and Burkard Hillebrands — FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany

Spin pumping is highly sensitive to the interface properties and composition of a given material system and in particular to the magnetic proximity effect (MPE). In order to optimize the spin transport across the interface, it is important to understand the different influences of these factors. In many spin pumping experiments, Pt and Ta are used to detect a spin current indirectly via the inverse spin Hall effect (ISHE). However, Pt has been shown to also exhibit MPE, which could have a substantial impact on the interface transparency and damping parameter. In this work, we investigate $Co_{40}Fe_{40}B_{20}$/X/Pt and $Co_{40}Fe_{40}B_{20}$/X/Ta multilayer systems, where X is Al, Ta or Cr with varying thicknesses. Contact between $Co_{40}Fe_{40}B_{20}$ and Pt gives rise to the MPE in Pt whereas this effect is not expected in Ta. In any case, even a thin NM spacing layer suppresses the MPE completely. We present VNA-FMR data on these systems and angle-resolved ISHE measurements, where spin rectification is separated from the spin pumping signal.

Support by M-era.Net and HEUMEM is acknowledged.

MA 21.59 Tue 9:30 Poster A

Spin Hall effect in amorphous W-Zr and W-Hf alloys — •Katharina Fritz and Markus Meinert — Center for Spinelectronic Materials and Devices, Department of Physics, Bielefeld University, Germany

In search for materials with large spin Hall effect, we investigated the binary alloys W-Zr and W-Hf. Thin films were prepared across the full range of stoichiometries for both alloys by magnetron co-sputtering. Due to the linear relation between the spin Hall angle and the resistivity, alloy compositions with high resistivity are expected to show a large spin Hall angle.

In both stoichiometry series we found peak values of the spin Hall angle accompanied with a significant increase of the resistivity. X-ray diffraction measurements connect these observations to a transition from a bcc solid solution to an amorphous material at this concentration. In the W-Zr series, the maximum spin Hall angle of $\Theta = -0.31$ is found at a tungsten content of 65 %, whereas in the W-Hf series the maximum spin Hall angle of $\Theta = -0.23$ appears at a tungsten content of 70 %. For lower tungsten content, the spin Hall angle decreases in both stoichiometry series. In the W-Hf series we find a linear relation between the spin Hall conductivity and the tungsten content irrespective of the structural phase transition.

MA 21.60 Tue 9:30 Poster A

Optimizing the spin Hall angle in ultrathin metallic films — •Christian Herschbach[1], Dmitry Fedorov[2], Martin Gradhand[3], and Ingrid Mertig[1,4] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]University of Luxembourg, L-1511 Luxembourg, Luxembourg — [3]University of Bristol, Bristol, United Kingdom — [4]Max Planck Institute of Microstructure Physics, Halle, Germany

The spin Hall effect (SHE) is one of the key effects in modern spintronics creating pure spin currents in nonmagnetic materials. The spin Hall angle (SHA) being the ratio of the transverse spin conductivity to the longitudinal charge conductivity serves as a good quantity for the effect's strength. During the last years, reported experimental and theoretical values of the SHA increased. While measurements on Pt-doped Au samples yielded a SHA of about 10% introduced as giant SHE [1], a SHA of 24% was published for thin-film Cu(Bi) alloys [2].

In this work we theoretically investigate Bi-doped ultrathin noble-metal films by means of an *ab initio* approach using density functional theory and linearized Boltzmann equation. We study various possibilities to optimize the SHE and forecast colossal SHAs slightly below 100% [4]. Furthermore, we identify systems with a strong anisotropy of the in-plane transport properties that lead to SHAs above 100%.

[1] Seki *et al.*, Nat. Mater. **7**, 125 (2008); [2] Niimi *et al.*, Phys. Rev. Lett. **109**, 156602 (2012); [3] Gradhand *et al.*, Phys. Rev. Lett. **104**, 186403 (2010); [4] Herschbach *et al.*, Phys. Rev. B **90**, 180406(R) (2014);

MA 21.61 Tue 9:30 Poster A

Probing the spin Hall effect in YIG/$Cu_{1-x}Ir_x$ bilayers at DC and terahertz frequencies — •Joel Cramer[1,2], Tom Seifert[3], Alexander Kronenberg[1], Felix Fuhrmann[1], Franziska Martin[1], Gerhard Jakob[1], Martin Jourdan[1], Tobias Kampfrath[3], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [3]Abteilung Physikalische Chemie, Fritz-Haber-Institut der Max-Planck-Gesellschaft, 14195 Berlin, Germany

The effective generation and detection of pure spin currents is a crucial ingredient for next-generation spintronic applications. The spin Hall effect and its inverse are in the focus of research, as they allow for an interconversion of charge and spin currents [1]. We investigate the inverse spin Hall effect of $Cu_{1-x}Ir_x$ thin films on yttrium iron garnet for a large range of Ir concentrations ($0.05 \leqslant x \leqslant 0.7$) [2]. Spin currents are triggered through the spin Seebeck effect, either by a DC temperature gradient or by ultrafast optical heating of the metal layer. The generated spin Hall current is detected by electrical contacts or measurement of the emitted THz radiation. With both approaches, we observe the same complex, non-monotonous concentration dependence. The coinciding results obtained for DC and ultrafast stimuli show that the studied material allows for efficient spin-to-charge conversion even on ultrafast timescales, thus enabling a transfer of established spintronic measurement schemes into the terahertz regime. [1] Sinova *et al.*, Rev. Mod. Phys. **87**, 1213 (2015) [2] Cramer *et al.*, arXiv:1709.01890

MA 21.62 Tue 9:30 Poster A

The influence of the Hall-bar geometry on the apparent spin Hall angle in harmonic Hall voltage measurements — •Lukas Neumann and Markus Meinert — Center for Spinelectronic Materials and Devices, Faculty of Physics, Bielefeld University, D-33501 Bielefeld, Germany

We investigate the influence of the Hall-bar geometry on the apparent spin Hall angle (SHA) in harmonic Hall voltage measurements which is a well established method to determine the SHA of a nonmagnetic metal/ferromagnet bilayer structure like Ta/CoFeB. Tantalum is a heavy metal with large spin-orbit coupling such that an in-plane current generates a substantial spin-orbit torque acting on the magnetization orientation of the ferromagnetic layer. The samples are patterned into Hall bars using electron beam lithography. Being located in an in-plane magnetic field an AC current through the Hall-bar generates a Hall-voltage whose second harmonic gives the apparent SHA. In the simplest model, the influence of the voltage pickup arms is neglected. Obviously, the current density distribution in the vicinity of the voltage pickup arms is not homogeneous and depends on the width of these arms. To systematically investigate this effect we varied the pickup arm width and observe a strong change of the apparent SHA as the pickup arm width is increased. In a symmetric Hall cross with fourfold rotational symmetry, the apparent SHA is reduced by about 30% with respect to the maximum value at narrow pickup arm width. We compare the measured values with simulations of the current density distribution.

MA 21.63 Tue 9:30 Poster A

Perpendicular magnetic anisotropy in magnetic insulator thin films — •Shilei Ding[1,2,3], Andrew Ross[2,3], Sven Becker[2], Joel Cramer[2,3], Jinbo Yang[1], Mathias Kläui[2,3], and Gerhard Jakob[2,3] — [1]State Key Laboratory for Mesoscopic Physics, School of Physics, Peking University, Beijing 100871, China — [2]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [3]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany

Rare earth iron garnets (RIG) are drawing great interest in recent years due to their excellent performance in the field of spintronics because of the low Gilbert damping and long spin diffusion length. RIG/normal metal heterostructures have been widely used to study Spin Hall magnetoresistance, spin seebeck effect phenomena which are mainly induced by a spin current through the interface. One of the more attractive possibilities effect is the current induced control of magnetization in perpendicular magnetic anisotropy (PMA) RIG by spin orbit torque (SOT). Here we present the successful growth of thulium iron garnet (TmIG) and gadolinium iron garnet (GIG) by pulsed laser deposition. PMA is induced by lattice strain between films and substrate. The obtained PMA garnet films show low coercivity (< 5 mT) with thickness under 10 nm, which will benefit the study of magnetic moment switching with low current density.

MA 21.64 Tue 9:30 Poster A

Néel vector readout by spin Hall magnetoresistance in NiO/Pt thin films — Lorenzo Baldrati[1], •Andrew Ross[1,2], Tomohiko Niizeki[3], Christoph Schneider[1], Rafael Ramos[3], Joel Cramer[1,2], Olena Gomonay[1], Mariia Filianina[1,2], Tatiana Savchenko[4], Daniel Heinze[1], Armin Kleibert[4], Eiji Saitoh[3,5], Jairo Sinova[1], and Mathias Kläui[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Germany — [3]Advanced Institute for Materials Research, Tohoku University, Japan — [4]Swiss Light Source, PSI, Switzerland — [5]Institute for Materials Research, Tohoku University, Japan

Electrically reading the orientation of the Néel vector is fundamental for the development of antiferromagnetic (AFM) spintronics. Here, we report on spin Hall magnetoresistance (SMR) measurements of a AFM, thin film epitaxial nickel oxide (NiO)/platinum (Pt) heterostructure on MgO (001). We find that the resistance of the Pt film depends on the angle θ between an injected charge current $\mathbf{J}_c$ and the Néel vector of the NiO, **N**. It exhibits the characteristic $\sin^2(\theta)$ dependence for SMR signals, but with a 90 ° shift as compared to SMR signals obtained for insulating ferrimagnets. The strength of the SMR signal increases for increasing field, with an onset of the signal at 1-3 T[1] and we propose a model based on the movement of magnetoelastic domains. From the observed SMR ratio, we estimate the spin mixing conductance at the NiO/Pt interface to be greater than $1\text{x}10^{14}\ \Omega^{-1}\ \text{m}^{-2}$. [1]Baldrati et al, arXiv:1709.00910 (2017)

MA 21.65 Tue 9:30 Poster A

Unidirectional spin Hall magnetoresistance and thermal effects in Pt/Co, Ta/Co and multilayer systems — •Anastasiia Moskaltsova, Daniel Meier, Timo Kuschel, Jan-Michael Schmalhorst, and Günter Reiss — CSMD, Department of Physics, Bielefeld University, Germany

Recently, the unidirectional spin Hall magnetoresistance (USMR) has been found in ferromagnetic (FM)/heavy metal (HM) bilayer systems [1]. Magnetoresistive (MR) effects, like anisotropic magnetoresistance and spin Hall magnetoresistance are usually symmetric with the current polarity and proportional to m^2, while by using USMR one can detect a change in resistance by reversing current or magnetization direction. This is related to the spin accumulation at the FM/HM interface induced by spin Hall effect. This effect can be potentially used in applications for sensing and multi-state memory devices [2]. In this work we present harmonic measurements of angular dependences in Pt/Co, Ta/Co and multilayer systems. By varying the FM/HM layer order and stack repetitions we can extract the information about the interface influence on USMR as well as other MR effects. It was found that variation of the FM/HM layer order can give rise to a more complex second harmonic signal, which can be explained by additional thermoelectric contributions. Thus, the layer thickness and ordering play significant role and can change the contribution of the thermal effects, while keeping the magnitude of the USMR constant.

[1] C. O. Avci et al., Nat. Phys. 11, 570 (2015)
[2] C. O. Avci et al., Appl. Phys. Lett. 110, 203506 (2017)

MA 21.66 Tue 9:30 Poster A

The structural and magnetic properties of Fe-Sn ferromagnetic compounds — •Bahar Fayyazi, Konstantin Skokov, Tom Faske, and Oliver Gutfleisch — Technische Universität Darmstadt, Germany

Uniaxial ferromagnets with high anisotropy composed of earth-abundant elements are of interest for development of new permanent magnets. Potentially, high values of anisotropy energy are possible in 3d compounds. The Fe-Sn system contains 3 ferromagnetic compounds, namely Fe3Sn, Fe5Sn3, and Fe3Sn2 [1]. In this work, the intrinsic magnetic properties such as spontaneous magnetization, anisotropy field and Curie temperature were obtained for the Fe-Sn compounds by measurements on single crystals. The magnetic measurements were performed along 3 crystallographic directions [001], [100] and [120] of the hexagonal structure in a temperature range of 5-600K. The change of anisotropy with temperature and occurrence of spin reorientation transition will be discussed. Additionally, the structural properties of them measured on single crystal diffractometer will be reported.

[1] Fayyazi, B., et al., Bulk combinatorial analysis for searching new rare-earth free permanent magnets: Reactive crucible melting applied to the Fe-Sn binary system. Acta Materialia, 2017. 141: p. 434-443.

MA 21.67 Tue 9:30 Poster A

Additive Manufacturing of Permalloy: Magnetic and Structural Properties — •Hanna Schönrath, Stefan Kilian, Jan T. Sehrt, Marina Spasova, Gerd Witt, and Michael Farle — Universität Duisburg-Essen, Germany

Permalloy (Fe21.5 at.-%, Ni78.5 at.-%) exhibits remarkable soft magnetic properties [1]. Thus it finds its application for example in sensors or inductive devices. In conventional manufacturing methods, several drawbacks include a degradation of magnetic properties [2], geometrical limitations and a waste of material due to post-processing. An alternative approach is the use of Additive Manufacturing (AM) technologies. In particular, Laser Beam Melting (LBM) allows the fabrication of metallic parts with individualized near net shaped structures and complex geometries, which cannot be manufactured with other techniques [3].

We report the manufacturing of LBM-cubes with an edge length of 5 mm using a magnetic powder blend with 21.5 at.-% Fe and 78.5 at.-% Ni. For high energy input during the production, Energy-dispersive X-ray Spectroscopy revealed a line-shaped segregation of Fe and Ni at the surface of the cubes and a $FeNi_3$ phase in the bulk material. Additionally Magnetometry indicated an increase of the saturation magnetization of the bulk material with increasing energy input.

[1] Jiles, D.C. Acta Mater. **51** (2003) 5907.

[2] Fenineche, N.E., et al. Mater. Lett. **58** (2004) 1797.
[7] Frazier, W.E. JMEPEG **23** (2014) 1917.

MA 21.68 Tue 9:30 Poster A

Large uniaxial magnetostriction with sign inversion at the first order phase transition in Mn_2GaC films — Iuliia Novoselova[1], •Ruslan Salikhov[1], Andrejs Petruhins[2], Arni Ingason[2], Johanna Rosen[2], Ulf Wiedwald[1], and Michael Farle[1,3] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [2]Department of Physics, Linköping University, Linköping, Sweden — [3]Center for Functionalized Magnetic Materials, Immanuel Kant Baltic Federal University, Kaliningrad, Russia

$M_{n+1}AX_n$ (n = 1,2,3) phases are a family of inherently nanolaminated hexagonal compounds. The new Mn_2GaC MAX phase was synthesized as hetero-epitaxial films containing Mn as the exclusive M-element [1]. Here, we present a comprehensive study of magnetic phase transitions in the Mn_2GaC films. The Néel temperature is $T_N \sim 507$ K, at $T_t = 214$ K the material undergoes a first order phase transition from antiferromagnetic (AFM) above T_t to a non-collinear AFM spin structure. Both states show large uniaxial c-axis magnetostriction of 450 ppm. Remarkably, the magnetostriction changes sign, being compressive (negative) above T_t and tensile (positive) below the T_t. The sign change of magnetostriction coefficient across the phase transition is a consequence of the layered structure and competing AFM and FM exchange interactions between magnetic atomic layers. The sign change of the magnetostriction is accompanied by a sign change in the magnetoresistance indicating a coupling between the spin, lattice and electrical transport properties. The work is supported by DFG Grant SA 3095/2-1. [1] Dahlqvist, M. et al. Phys. Rev. B 93, 014410 (2016).

MA 21.69 Tue 9:30 Poster A

Real-time dynamics of the Kosterlitz-Thouless transition in a magnetic layer on a metallic system — •Simon Michel and Michael Potthoff — I. Institut für Theoretische Physik, Universität Hamburg

A theoretical approach is developed to study the real-time dynamics of topological excitations of a two-dimensional anisotropic magnetic layer which is coupled to a metallic substrate. To this end, we solve the equations of motion for three-component classical spins on the square lattice which mutually interact via a direct in-plane exchange. In addition there is a local exchange coupling to the local magnetic moments of a system of noninteracting conduction electrons.

As a first step we consider the spin-subsystem only and study the vortex-unbinding Kosterlitz-Thouless transition in the equilibrium phase diagram. Within the real-time approach, this is done by starting from a random initial state, followed by a fictitious dissipative dynamics using a Gilbert damping term to generate a typical equilibrium state with given total energy. Thermodynamical expectation values are given as time averages. Here, we discuss the temperature dependence of the spin correlations, of the vortex density and of the average vortex-antivortex distance.

Eventually, our goal is to understand, on an atomic level, how to control topological excitations with the tip of a scanning-tunnelling microscope. In our model approach, this shall be done by computations of the real-time dynamics of the spin-electron hybrid system which is initiated by a strong local perturbation.

MA 21.70 Tue 9:30 Poster A

Magnetic Majorana fermions observed in the diluted Kitaev materials α-Ru1-xIrxCl3 — •Youngsu Choi[1,2], Dirk Wulferding[1,3], Peter Lemmens[1,3], Seunghwan Do[2], and Kwang-Yong Choi[2] — [1]IPKM, TU-BS, Braunschweig, Germany — [2]Chung-Ang Univ., Seoul, Korea — [3]LENA, TU-BS, Braunschweig, Germany

A Kitaev honeycomb lattice is a paradigmatic model that hosts Kitaev spin liquid and Majorana fermions. However, their experimental identification remains elusive in real Kitaev materials as non-Kitaev terms often induce a magnetically ordered state. We introduce spin vacancies to overcome this deadlock. In the diluted Kitaev materials α-Ru1-xIrxCl3, Raman scattering measurements uncover that moderate spin vacancies destabilize the zigzag antiferromagnetic order towards a short-range ordered state, while well-defined Majorana fermion excitations emerge under sizable dilutions. Furthermore, a structural evolution with Ir content is characterized by studying phonon modes.

Work supported by the Quantum- and Nanometrology initiative QUANOMET within project NL-4, the NTH School Contacts in Nanosystems and Korea NRF Grants (No. 2012-046138).

MA 21.71 Tue 9:30 Poster A

Magnetic properties of chain antiferromagnets $KFeS_2$ and $RbFeSe_2$ — •Zakir Seidov[1,2], Vladimir Tsurkan[3], Hans-Albrecht Krug von Nidda[1], Irina Filipova[3], Dorina Croitori[3], Axel Günther[1], Airat Kiiamov[4], Lenar Tagirov[4,5], Farit Vagizov[4], Tatyana Gavrilova[5], and Alois Loidl[1] — [1]EP V, EKM, University of Augsburg, D-86135 Augsburg — [2]Institute of Physics, ANAS, AZ-1143 Baku — [3]Institute of Applied Physics, Academy of Sciences of Moldova, MD-20208 Chisinau — [4]Institute of Physics, Kazan Federal University, RUS-420008 Kazan — [5]E.K.Zavoisky Physical-Technical Institute, RAS, RUS-420029 Kazan

The ternary iron chalcogenides $KFeS_2$ and $RbFeSe_2$ consisting of chains of edge-sharing FeX_4 (X = S, Se) tetrahedra have been investigated by means of magnetic susceptibility, specific heat, Mössbauer, and ESR measurements. The single crystals exhibit collinear antiferromagnetic (AFM) order with strongly reduced moments below 252 K and 248 K, respectively. For both compounds the small anomaly in $C(T)$ and the corresponding low value of entropy at T_N indicate a significant spin reduction and the existence of AFM fluctuations even far above T_N. Mössbauer parameters determined in the entire temperature range indicate that iron in $RbFeSe_2$ is in ferric (trivalent) state having strong covalent bonding to selenium ligands. The measured hyperfine field of 216 kOe at 4.2 K is quite reduced as compared to that in high-spin ferric compounds corroborating the strong spin reduction of Fe^{3+}. The high-temperature susceptibility data of $KFeS_2$ and $RbFeSe_2$ suggest a one-dimensional metallic character along the chains.

MA 21.72 Tue 9:30 Poster A

Magnon-phonon coupling in hybrid-nanostructures — •T. Luschmann[1,2], D. Schwienbacher[1,2,3], R. Gross[1,2,3], M. Weiler[1,2], and H. Huebl[1,2,3] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Nanosystems Initiative Munich, München, Germany

Phononic crystals are ideal candidates for localizing phonons up to GHz frequencies in phononic cavities [1]. Combining these structures with magnetic materials with similar magnetic resonance frequencies should allow for resonant, artificial magnon-phonon coupling. We present a finite element study for the realization of phononic cavities in SiN mechanical resonators and discuss the magnon-phonon coupling in these devices. In addition, we will present first samples and measurements.

[1] M. Eichenfield et al. Optomechanical Crystals, Nature **462** (2009).

MA 21.73 Tue 9:30 Poster A

Magneto-resistance measurements in para- and ferromagnetic $Fe_{60}Al_{40}$ nanowires — Vico Liersch[1], •Alexander Schmeink[1], Benedikt Eggert[2], Tobias Warnatz[1], Sebastian Wintz[1,3], Jonathan Ehrler[1], Roman Böttger[1], Gregor Hlawacek[1], Kay Potzger[1], Jürgen Lindner[1], Jürgen Fassbender[1], Artur Erbe[1], Heiko Wende[2], and Rantej Bali[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]CENIDE & Universität Duisburg-Essen, Duisburg, Germany — [3]Paul Scherrer Institut, Villigen PSI, Switzerland

Paramagnetic (PM) B2 $Fe_{60}Al_{40}$ can be disordered into the ferromagnetic (FM) A2 structure using light noble gas ions.[1] The transition can be adjusted using the ion fluence and reversed via annealing thus providing a tunable magnetic material.

Using a focused Ne^+ ion beam of ∼2 nm spot-size it is possible to locally induce disorder in thin films of such a material, creating FM regions in PM surroundings.[2] This enables patterning of FM|PM|FM structures in the current-perpendicular-to-plane geometry.

FM stripes of ∼100 nm widths with PM spacings down to 50 nm were written onto 40 nm thick B2 $Fe_{60}Al_{40}$. The reversal fields of the patterned FM stripes are adjustable via the stripe width, enabling multiple magnetic configurations. Magneto-transport properties of the ion-patterned structures as well as the effect of joule heating on the stability of A2 $Fe_{60}Al_{40}$ are reported.

[1] E. Menéndez *et al.* New J. Phys. **10** 103030 (2008).
[2] F. Röder *et al.* Sci. Rep. **5** 16786 (2015).

MA 21.74 Tue 9:30 Poster A

A nanoscale approach in wireless power transfer — •Marius Wodniok and Sonja Schöning — University of Applied Sciences Bielefeld, Bielefeld, Germany

Inductive applications become an every day tool in electronics and electronic parts as for example in phones and cars. In that matter the wireless power transfer needs to get optimized in concerns of speed, efficiency and (more important) displacement tolerance. Therefor it is essential to guide the magnetic field lines and form a focused stray field. In heating applications power transfer shall additionally occur homogenous corresponding to flat receivers like cooking dishes.

To realize these demands and make a nanoscale approach a material study for surrounding and receiving parts is performed to determine the key material characteristics for an optimized wireless power transfer. Beforehand simulations using COMSOL Multiphysics are run for a simplified system of an induction stove to predefine key characteristics and narrow down the selection of suitable materials. The material study itself includes measurements of the magnetic, electric and thermal properties in correlation to the power transfer. Following these investigations, nanoparticles and thin films will be tailored for an optimized wireless power transfer.

MA 21.75 Tue 9:30 Poster A

Magnetic coupling effects in ordered arrangements of magnetite nanoparticles — •Nils Neugebauer[1], Matthias T. Elm[1,2,3], and Peter J. Klar[1,2] — [1]Institute of Experimental Physics I, Heinrich-Buff-Ring 16, 35392 Gießen, Germany — [2]Center for Materials Research (LaMa), Heinrich-Buff-Ring 16, 35392 Gießen, Germany — [3]Institute of Physical Chemistry, Heinrich-Buff-Ring 17, 35392 Gießen, Germany

Fabrication of magnetic nanoparticle arrangements have attracted great interest for modern research due to their potential for various applications such as recording tapes, spintronic and magnetoresistive random access memory (MRAM). The influence of the distance between magnetic arrangements on the behavior of the macroscopic properties has not been sufficiently investigated yet. The knowledge of these properties is of enormous significance, e.g. for increasing the storage density of memory devices. The present study is performed to determine the distance dependence of the coupling between magnetic nanoparticle arrangements. By using electron-beam lithography and the meniscus force deposition method, structures with defined size and controlled spacing down to a few tens of nanometers can be assembled. Those structures were filled with magnetite (Fe_3O_4) nanoparticles with diameters of 20 nm. Ferromagnetic resonance measurements (FMR) are used to characterize the properties of those arrangements. It is revealed that there is a critical distance where coupling occurs, and that the nature of the interaction is also dependent on the spatial arrangement of the nanoparticle arrangements.

MA 21.76 Tue 9:30 Poster A

Tuning of the Ni:Fe ratio of flexible thin-film giant magnetoimpedance sensors — •Gregor Büttel and Uwe Hartmann — Institute of Experimental Physics, Saarland University, P. O. Box 151150, D66041, Saarbrücken, Germany

Permalloy-based giant magnetoimpedance (GMI) sensors have been integrated onto Si cantilevers to investigate their potential for the detection of strain and as flexible sensors. The devices allow to apply compressive and tensile strain and to record images of the corresponding magnetic domains by magneto-optical Kerr wide-field microscopy. By tuning the Ni:Fe ratio to a negative magnetostriction constant a strain-gauge factor of nearly 200 is reached in the ferromagnetic resonance regime of the GMI effect [1].

In case of nearly zero magnetostriction the effective anisotropy field remains stable under large applied tensile/compressive strain and no broadening/narrowing of the hysteresis and impedance curve occurs. However, in the low-field and MHz regime a significant modification of the impedance curve was found, which is attributed to domain-wall resonance and a corresponding change of permeability/impedance.

[1] Buettel, G. et al., APL, in press

MA 21.77 Tue 9:30 Poster A

Application of 3D Lithography — •Christian Denker[1], Cornelius Fendler[2], Julia Bethune[4], Nina Meyer[1], Tobias Tubandt[1], Finn-F. Lietzow[1], Neha Jha[1], Chris Badenhorst[3], Alena Rong[5], Jakob Walowski[1], Mark Doerr[3], Raghvendra Plankar[4], Mihaela Delcea[5], Uwe T. Bornscheuer[3], Robert Blick[2], Swadhin Mandal[6], and Markus Münzenberg[1] — [1]Institut für Physik, Universität Greifswald, Germany — [2]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Germany — [3]Institut für Biochemie, Universität Greifswald, Germany — [4]Institute of Immunology and Transfusion Medicine, University Medicine Greifswald, Germany — [5]Centre for Innovation Competence - Humoral Immune Reactions in Cardiovascular Diseases, Universität Greifswald, Germany — [6]Indian Institute of Science Education and Research Kolkata, India

3D 2-Photon-Lithography, originally developed for 3D photonic crystals, opens a wide range of new possible applications in many other fields, e.g. life sciences, micro-optics and mechanics [1]. We will present our recent applications of 3D 2-Photon-Lithography and show 3D evaporation masks for in-situ device fabrication using different deposition angles, infra-red laser light focusing lenses directly fabricated on optical fibers, tunnel structures for guiding growth of elongated cells, pillars for investigation of cell mechanics and master-mold fabrication for Polydimethylsiloxane (PDMS) micro-fluidic channels.

[1] J. K. Hohmann et al., Adv. Optical Mater. 3 (2015) 1488

MA 21.78 Tue 9:30 Poster A

Electronic transport in van der Waals layered Kagome lattice Nb3X8 Cluster Compound — •Edouard Lesne[1], Jiho Yoon[1], John P. Sheckelton[2], Chris Pasco[2], Tyrel M. McQueen[2], Stuart S. P. Parkin[1], and Mazhar N. Ali[1] — [1]Max Planck Institute of Microstructure Physics, Halle (Germany) — [2]Johns Hopkins University, Baltimore (USA)

Geometrically frustrated materials based on a Kagome lattice have been long studied as promising Quantum Spin-Liquid candidates. Of particular interest are metallic spin liquids * theorized to host exotic transport properties including high temperature superconductivity [1].

Recently, the 2D van der Waals cluster compound Nb3Cl8, which has a Nb Kagome lattice, has been reported as a potential spin liquid material [2]. Due to its insulating behavior, electronic transport properties and their link to the exotic magnetism have not been investigated.

Here we report on electronic transport measurements in 10-100nm thin flakes of Nb3X8 (X= Cl, Br) in Hall bar geometries, fabricated via standard micromechanical exfoliation techniques combined with photolithography and ion-beam sputtering deposition. We further resort to electrostatic doping in a back-gate geometry, and to top-gating via ionic liquid to metallize the compound and probe a prospective metallic spin liquid state.

[1] P. W. Anderson, Science 235, 1196 (1987) [2] J. P. Sheckelton et al., Inorg. Chem. Front. 4, 481 (2017)

MA 21.79 Tue 9:30 Poster A

Downscaling of planar Hall effect sensors for optical transparency and small volumes — •Luca Marnitz, Karsten Rott, Karl-Josef Dietz, Dario Anselmetti, and Günter Reiss — Bielefeld University

Magnetic field sensors based on the Planar Hall Effect (PHE) have been used to sense the stray field of magnetic nanoparticles induced by the self-field of the sensor current. Prior reports either use the shape anisotropy of the sensor to induce effective single domain behaviour [1] or use exchange-biased ferromagnets for example in a PHE Bridge (PHEB) layout [2].

However, these sensors either have a large surface area of up to several mm^2 [1], which is problematic for small sample volumes and/or are optically non-transparent due to their relatively large thickness.

In this work we prepared μm-sized optically transparent PHE-sensors for magnetic nanoparticle detection and simultaneous optical observation in an optical microscope.

Both the effects of downscaling the area and the thickness of the active sensors are analyzed regarding their feasibility for detecting the particle-surface distance in an optical microscope equipped with a magnetic tweezer. This technique could allow the use of smaller particles and tailored particle shapes to analyze the stretching and twisting of biomolecules.

[1] Mor et al., JAP 111, 07E519 (2012)
[2] Henriksen et al., JAP 119, 093910 (2016)

MA 21.80 Tue 9:30 Poster A

Efficient numerical relaxation of antiferromagnetic spin textures — •Andrew Fingers, Hristo Velkov, Matthias Sitte, Helen Gomonay, Daniele Pinna, Jairo Sinova, and Karin Everschor-Sitte — Johannes Gutenberg-Universität, Mainz, Germany

The literature is plentiful of both open source and commercial software for the analysis of ferromagnetic dynamics. Current approaches to antiferromagnetic systems simply modify the existing codes by either altering the sign of the exchange constant or only covering the dynamics of the staggered field in the large coupling limit. For antiferromagnetic systems, however, the situation is more complex due to the different energy and time scales involved. As an example, just modifying the sign of the exchange constant can lead to nontrivial numerical errors. Already the relaxation of an antiferromagnetic texture on its own is a complex task and the algorithms cannot just be transferred from the ferromagnetic case. We are developing a suite of solvers tailored for antiferromagnetic systems. We demonstrate a relaxation solver and apply it to the specific example of an antiferromagnetic skyrmion.

MA 21.81 Tue 9:30 Poster A

Inverse Coil Design by Simulation based Optimization — •Lennart Weber, Simon Bekemeier, and Christian Schröder — Bielefeld Institute for Applied Materials Research (BIfAM), Computational Materials Science and Engineering (CMSE), University of Applied Sciences Bielefeld, Department of Engineering Sciences and Mathematics, Interaktion 1, D-33619 Bielefeld

Inductive power transfer is nowadays a widely used technology. One example is inductive heating, where the used coils are usually planar with homogeneous winding distances. With regard to energy efficiency, comfort and electromagnetic compatibility it is desirable to start from an optimal magnetic field distribution and derive the necessary coil geometry from it. Such an approach requires inverting the Biot-Savart law, which poses an ill-posed problem. This can usually be addressed by so-called target-field methods. Here, we propose a different approach, namely a direct approach using a parametric representation of the coil geometry. Based on this we solve the forward problem, i.e. calculate the magnetic field and optimize the parameters of the coil by Simulated Annealing in order to minimize the difference between the present field and the target field. Furthermore, we examine machine learning algorithms and other optimization techniques, beside Simulated Annealing, to speed-up our calculations and improve our approach.

MA 21.82 Tue 9:30 Poster A

A target field approach for the design of non-conventional 3-D coils — •Assja Laas and Christian Schröder — Bielefeld Institute for Applied Materials Research (BIfAM), Computational Materials Science and Engineering (CMSE), University of Applied Sciences Bielefeld, Department of Engineering Sciences and Mathematics, Interaktion 1, D-33619 Bielefeld

The design of coils for high-frequency applications in the area of inductive energy or information transfer is a challenging task. For efficiency and energy reasons the geometry and topology of the coils needs to be adapted to the corresponding application. In our study we focus on the design of three dimensional induction heating coils by an inverse methodology. Induction hubs are operating at frequencies where a time-harmonic representation of the Maxwell equations can be used to determine the axial component of the magnetic field B(r). A target field is specified over a certain region and an approximation of the current density through a Fourier series expansion is derived which generates the desired field. Because of the ill-posed nature of this problem, a Tikhonov regularization with a minimum gradient term is used to calculate the unknown parameters of the Fourier series expansion. Based on this, the coil windings are usually determined using a stream function approach. However, because of the three dimensionality of the problem this is not possible. Instead, we generate a current density map, from which the winding patterns can be derived.

MA 21.83 Tue 9:30 Poster A

Motion Characteristics of Exchange Bias Capped Janus Particles in Dynamic Magnetic Stray Field Landscapes — •Andreea Tomiţa, Rico Huhnstock, Meike Reginka, Dennis Holzinger, 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

Transport systems and self-propelled particles offer interesting prospects for research in a wide spectrum of applications like biomedicine, sensors and lab-on-a-chip devices. The system that we propose takes a novel approach by combining the multifunctionality of Janus particles with the strict control and confinement of their locomotion in an artificial magnetic field landscape. The Janus particles are fabricated to have a magnetic cap made of an exchange bias thin film system and a non-magnetic material respectively, in this case the later being silica, a material with high functionalization potential. This allows for the distinct study of the Janus particles' coupled translational-rotational transition and motion dynamics when exposed to dynamically changing magnetic stray field landscapes. The asymmetry of the particles, combined with the magnetic field landscape of the substrate, creates the possibility of a tailored assembly of several particles pointing in a direction dictated by the power-balance of the forces acting on them.

MA 21.84 Tue 9:30 Poster A

Size effect of exchange interaction parameters for FePd nanoparticles — •Svitlana Ponomarova, Iurii Koval, and Oleksandr Ponomarov — Institute for Metal Physics the NAS of Ukraine

Magnetic properties of materials are measured by various types of external influences. From this prospective FePd bulk and nano alloys show interesting features: increase of high magnetic anisotropy in the ordered L10 phase, Invar effect, and martensitic transformation at low temperatures.

In this paper we calculated exchange interaction parameters - exchange integrals - in FePd magnetic nanomaterials for Fe-Fe, Pd-Pd, Fe-Pd atom pairs within a nanoparticle under different conditions.

The Heisenberg model for the system of randomly located spins concerning their slowly-relaxing arrangement was updated for binary solid solution with two magnetic components. Magnetic properties (Curie temperature, etc.) may be easily varied by nanoparticle size. For this readon size effect is additional control factor which was taken into consideration for nanoparticles.

Basically we focused on analysis of:

1. the correlation between exchange interaction parameters and characteristics of martensitic transformation;

2. influence of an external pressure and an atomic ordering effect on exchange integrals.

MA 21.85 Tue 9:30 Poster A

Monte-Carlo simulation studies on interacting 3D nanoparticle supercrystals — •Mauricio Cattaneo, Michael Smik, Oleg Petracic, and Thomas Brückel — Jülich Centre for Neutron Science JCNS and Peter Grünberg Institut PGI, JARA-FIT, Forschungszentrum Jülich GmbH, 52425 Jülich

The assembly of magnetic nanoparticles into large 3D structures constitutes a novel way of fabricating artificial materials that show properties that are not found in conventional systems. A detailed understanding of the magnetic properties is impeded by the huge number of contributing parameters as well as the difficulty in probing the internal magnetic structure in situ. Monte-Carlo Simulations offer the possibility to predict numerically possible magnetic low energy states. Sufficiently small nanoparticles can be considered as single domain, which may be modelled as an effective superspin. In contrast to atomic spins, the dominating inter-particle interaction is the dipole-dipole interaction. We simulated iron oxide nanoparticles in a fcc superlattice structure with various lattice constants in order to tune the interaction strength. An Onsager-like mean-field approach has been implemented in order to increase the performance of the basic Metropolis scheme. In the limit of vanishing magnetocrystalline anisotropy, several low-energy states but no unique ground state have been observed.

MA 21.86 Tue 9:30 Poster A

Synthesis and study of magnetic nanoparticle systems of iron oxide, cobalt and their mixtures — •Svetlana Klimova, Nadine Fokin, Inga Ennen, Daniela Ramermann, and Andreas Hütten — Bielefeld University, Bielefeld, Germany

Magnetic nanoparticles (NPs) have potential for various applications such as sensors, ferro*uidics, high-frequency electronics, high performance permanent magnets, magnetic refrigerants, and catalytic systems. For producing and using magnetic NPs there are three key issues, which dominate the magnetic properties of magnetic NPs and their ensembles: *nite size effects, surface effects, interparticle interactions. Reducing the size leads to quantum con*nement and modi*es the properties at the nanoscale. Exchange bias like hysteresis shifts can be observed in ferromagnetic NPs, in which the surface behaves like a spin glass, which is formed due to *nite-size and surface effects. Furthermore, surface effects are related to the symmetry breaking of the crystal structure at the boundary of each magnetic NP. This work focuses on the synthesis of systems of iron oxide, cobalt and NP mixtures of different sizes and different magnetic phases. Comparing structural with magnetic characterization will reveal the magnetic interactions. Moreover, the resulting magnetic transport properties will be presented and discussed.

MA 21.87 Tue 9:30 Poster A

Fabrication and Magnetic characterization of exchange-biased Janus Particles — •Meike Reginka[1], Andreea Tomita[1], Rico Huhnstock[1], Thomas Kusserow[1], Kai Arstila[2], Dennis Holzinger[1], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Department of Physics, University of Jyväskylä, Suorvontie 9, FI-40014 Jyväskylä

Research in the field of point-of-care technology requires bio-functionalized particles, that allow for remotely controllable actuation in microfluidic processes, e.g. via external magnetic fields. In order to magnetically address the particles' degrees of motion, an exchange bias layer system was introduced on top of silica microspheres resulting in magnetic Janus particles. The sputter-deposited exchange bias system exhibits an unidirectional anisotropy, and thus, giving rise to a pinned magnetization distribution within the spherical half shell. For experimental verification the magnetic properties of the designed particles were investigated by Magnetic Force Microscopy and Kerr magnetometry besides other imaging methods on the nanometer scale, namely Helium Ion Microscopy, Focused Ion Beam and Scanning Electron Microscopy. Additionally, the addressability of the particles is shown in dynamic microfluidic experiments under externally applied rotational magnetic fields.

MA 21.88 Tue 9:30 Poster A

Temperature behavior of specific heat of hexagonal spin ice models with different interaction radius — Yuriy Shevchenko[1,2], •Aleksandr Makarov[1,2], Petr Andriushchenko[1,2], and Konstantin Nefedev[1,2] — [1]Department of Computer Systems, School of Natural Sciences, Far Eastern Federal University, Vladivostok, Russian Federation — [2]Institute of Applied Mathematics of Far Eastern Branch, Russian Academy of Science, 7 Radio Str, Vladivostok, Russian Federation

By Wang-Landau method the problems of temperature behavior of specific heat were solved for hexagonal lattice models with dipole short-range, as well as long-range interaction and free boundary conditions. We observe an anomalous behavior of specific heat for such lattices. It is established that systems of a finite number of Ising spins with long-range dipole interactions can have unusual thermodynamic properties that are characterized by the presence of several peaks of the specific heat in the absence of an external magnetic field. There is no phase transition in the model with the nearest-neighbor interaction on a hexagonal lattice, while the temperature behavior of the specific heat exhibits a singularity in the same model for long-range interaction.

MA 21.89 Tue 9:30 Poster A

Scanning electron microscopy with polarization analysis on ex-situ sputter-deposited ultrathin Ir\Co\Pt films — •Susanne Kuhrau, Fabian Kloodt-Twesten, Jochen Wagner, Robert Frömter, and Hans Peter Oepen — Center for Hybrid Nanostructures, Universität Hamburg, Germany

Scanning electron microscopy with polarization analysis (SEMPA) is a magnetic imaging technique with the capability to measure two components of the magnetization simultaneously. Due to its surface sensitivity, samples studied with SEMPA are usually prepared in situ. Ex-situ prepared samples are generally capped to prevent oxidation during transfer. It is commonly assumed that capping with non-magnetic material in the range of nm will deteriorate the magnetic contrast, particularly with strong spin scatterer as Pt. Before the SEMPA measurement the capping layer is either removed by sputtering or dusted by Co or Fe to establish magnetic contrast. However, both methods influence the properties of the sample, either due to intermixing of the upper layers or adding additional magnetic material. By means of a wedge shaped Pt capping layer we have investigated the magnetic contrast of $\{\mathrm{Ir\backslash Co\backslash Pt}\}_n$ ($n = 1, 2$) samples. Magnetic domains can be imaged up to the maximum Pt thickness of 2 nm. A contrast reduction due to oxidation as well as capping has been analyzed as a function of Pt thickness. The maximum of the magnetic contrast found around 1 nm Pt thickness, yielding 30% of the pure Co contrast.

MA 21.90 Tue 9:30 Poster A

Room-temperature antiferromagnetic order in individual goethite nanoparticles — •David M. Bracher[1], Tatiana M. Savchenko[1], Marcus Wyss[2], Giorgia Olivieri[3], Matthew A. Brown[3], Frithjof Nolting[1], Martino Poggio[2], and Armin Kleibert[1] — [1]Swiss Light Source, Paul Scherrer Institut, CH-5232 Villigen, Switzerland — [2]Department of Physics and Astronomy, University of Basel, CH-4056 Basel, Klingelberstrasse 82, Switzerland — [3]Laboratory for Surface Science and Technology, Department of Materials ETH Zürich, CH-8093,HCI G543

Nanoscaled antiferromagnets are of profound interest for future spintronic devices and novel materials. The absence of effective magnetic moments renders the investigation of antiferromagnetic material at the nanoscale very challenging. We tackle this issue by combining temperature- and orientation-dependent X-ray linear dichroism (XLD) spectromicroscopy by means of X-ray photoemission electron microscopy with scanning electron microscopy (SEM). The temperature dependen XLD signal of the individual goethite (α-FeOOH) nanoparticles suggest a mostly reversible magnetic phase transition around the Néel temperature (TN=400 K) of bulk goethite despite of the polycrystalline structure of nanoparticles. Comparing the spatially resolved XLD spectra with SEM images allows us to correlate the magnetic properties with the morphology of individual goethite nanoparticles.

MA 21.91 Tue 9:30 Poster A

Characterization of a Fresnel Zone Plate for magnetic imaging with high harmonic radiation — •Tobias Heinrich[1], Sergey Zayko[1], Ofer Kfir[1,2], and Claus Ropers[1] — [1]University of Göttingen, 4th Physical Institute, Göttingen, Germany — [2]Physics Department, Technion - Israel Institute of Technology, Haifa 32000, Israel

The development of bright circularly polarized high harmonic radiation [1,2] has recently enabled nanoscale magnetic imaging with sub-50-nm resolution using x-ray magnetic circular dichroism [3]. Here, we explore possibilities of enhancing this imaging approach utilizing a Fresnel zone plate (FZP). Such a setup will provide the opportunity for a direct and robust real-space image acquisition or can be used in a combination with lensless techniques to increase the irradiance at the sample.

In this work, a Fresnel zone plate suitable for use in a high-harmonic setup was designed and characterized. The resulting wave front was analyzed using a 3-D caustic measurement. By employing a pinhole scan, wave fronts of different diffraction orders were identified and separately evaluated. Using coherent diffractive imaging, the complex exit wave of the FZP was retrieved, yielding a focal spot size of 160 nm. A total first order diffraction efficiency of 4.5 % was estimated. With such an upgrade, the high-harmonic imaging setup will benefit from the opportunity for spatially resolved x-ray photoelectron spectroscopy in a scanning geometry. [1] Fleischer *et all.*, Nature Photonics **8**, 543-549 (2014) [2] O. Kfir *et all.*, Nature Photonics **9**, 99-105 (2015) [3] O. Kfir, S. Zayko *et all.*, arXiv:1706.07695

MA 21.92 Tue 9:30 Poster A

Steps toward a new imaging method in biological systems — •Gerhard Wolff, Simon Schmitt, Christian Osterkamp, Liam McGuinness, Boris Naydenov, and Fedor Jelezko — Institute for Quantum Optics, University Ulm, Germany

In the last century NMR established itself as key technology for non-destructive investigation of molecules and chemical reactions. As traditional NMR is reaching its limits in sensitivity and in spatial resolution new ways a new approach is needed ti reach behind these limitations.

In the last decades quantum sensors have attracted more and more attention. One such quantum sensor is the nitrogen Vacancy (NV) center in diamond for which research groups recently showed nanoscale NMR spectroscopy using single molecule confocal microscopes.

Widefield microscopy has the advantage over single NV experiments that it allows one to increase the signal and reduce measurement time, thus increasing frequency sensitivity. The reduced spatial resolution is still sufficient for imaging of single cells.

However several challenges still remain, such as homogeneous magnetic fields over several hundred micrometers while still being adjustable in arbitrary directions as well as the generation of homogeneous microwave fields for coherent control of the NV ensemble.

This work seeks to develop recent groundbreaking experiments and establish a new imaging method for biological systems.

MA 21.93 Tue 9:30 Poster A

Improving X-ray Magnetic Microscopy at MAXYMUS — •Markus Weigand[1], Iullia Bykova[1], Michael Bechtel[1], Bartel VanWaeyenberge[2], Hermann Stoll[1], and Gisela Schütz[1] — [1]MPI for Intelligent Systems, Stuttgart, Germany — [2]Gent University, Gent, Belgium

MAXYMUS is a UHV Scanning Transmission X-ray Microscope (STXM) operated by the MPI for Intelligent Systems at a dedicated soft X-ray undulator beamline at Bessy II, which is a world leading instrument for time resolved magnetic microscopy.

It allows users to pump samples with a wide range of excitation types and frequencies and directly image the response of the sample with our self-build single photon detection and counting system, yielding resolutions of down to 20ps and 20nm in time and space. This capability can combined with a vector field system and UHV capability for concurrent surface and bulk measurements.

We will present a number of upgrades being made to the microscope to enhance the capabilities, including a helium cryostat and compatible high frequency sample holders for dynamic imaging <30K, improvements for higher excitation bandwidths above 30GHz as well as a high repetition rate synchronized laser being developed in cooperation with the Max-Born-Institute to allow optical pumping, both for thermal excitation as well as triggering of Austin switches for very fast dynamic imaging.

MA 21.94 Tue 9:30 Poster A

Ptychographic imaging of magnetic materials at MAXYMUS X-ray microscope — •Iuliia Bykova, Markus Weigand, Kahraman Keskinbora, Umut Sanli, Joachim Gräfe, Eberhard Goering, Hermann Stoll, Gunther Richter, and Gizela Schütz — Max-Planck-Institute for Intelligent Systems, Stuttgart, Germany

The size of magnetic features in modern magnetic materials can be scaled far below 100 nm that requires imaging with advanced resolution capabilities. Ptychography is the combination of diffraction imaging and scanning transmission microscopy that provides images of extended sample areas with wavelength limited resolution. Utilizing iterative reconstruction algorithms it provides phase and amplitude information about studied specimens. With possibility to use circular negative and positive polarized X-ray light these technique would allow to gain insight into the domain configuration of the magnetic structures, their shape and stability.

MAXYMUS X-ray microscope was upgraded with a fast in-vacuum CCD camera (PNSensor) with high readout speed up to 450 Hz, quantum efficiency >70% (for E>300eV) and RMS noise per pixel less than 3e-. Implementation of a fast CCD camera and in-house produced IBL FZPs at MAXYMUS allowed introduction of ptychographic imaging and, as a result, drastic improvement of imaging resolution. We are going to present latest results of ptychographic imaging of samples with magnetic contrast obtained at MAXYMUS microscope.

MA 21.95 Tue 9:30 Poster A

Unconvnetional X-ray Optics — •Kahraman Keskinbora, Umut T. Sanli, Margarita Baluktsian, and Gisela Schütz — Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany

First optic that comes to mind in any discussion of focusing X-rays, is just a binary Fresnel zone Plate with rectangular zone profiles. However, focusing X-rays with high efficiency or shaping the phase front with high fidelity necessitates more elegant and sophisticated micro/nano-structures. Here, we will discuss some of these unconventional X-ray optical devices useful for various X-ray beam-shaping scenarios.

MA 21.96 Tue 9:30 Poster A

Multilayer Fresnel zone plates — •Umut T. Sanli, Margarita Baluktsian, Markus Weigand, Iuliia Bykova, Gisela Schütz, and Kahraman Keskinbora — MPI for Intelligent Systems, Stuttgart, Germany

Multilayer type (ML) Fresnel zone plates (FZP) were first suggested 35 years ago and drew incredible attention in X-ray community as they can achieve very high aspect ratios which makes it theoretically possible to focus a very broad range of X-rays including very hard X-rays down to around 20 nm. Because of the needed high precision in zone positioning, circularity and the needed low zone roughness, ML-FZPs have suffered from lower than optimum efficiencies and lens aberrations. With our new insight into the fabrication method, which utilizes atomic layer deposition (ALD) technique to deposit the multilayer zones of the ML-FZP, we were able to fabricate high quality ML-FZPs and achieved astigmatism-free direct imaging with high diffraction efficiency for the first time in ML-FZP history [1], and resolved 15.5 nm structures, the world record direct imaging resolution achieved by an ML-FZP. With our ALD fabricated Multilayer Fresnel zone plates we aim for sub 10 nm imaging resolution.

MA 21.97 Tue 9:30 Poster A

Laser-assisted local magnetization switching across the spin reorientation transition in $DyCo_5$ antidots — •Jaime Sánchez-Barriga, Chen Luo, Sergio Valencia, and Florin Radu — Helmholtz-Zentrum Berlin für Materialien und Energie, Elektronenspeicherring BESSY II, Albert-Einstein-Str. 15, 12489 Berlin, Germany

The miniaturization required to achieve ultrahigh areal bit densities leads to new fundamental challenges in both growth of magnetic nanostructures and control of magnetic properties of ferrimagnets in low dimensions. Using photoelectron emission microscopy in combination with x-ray magnetic circular dichroism, we demonstrate the use of $DyCo_5$ ferrimagnetic antidot arrays for heat-assisted magnetic recording. This is achieved by exploiting the reorientation of the magnetic anisotropy which occurs just above room temperature, and by using trains of laser pulses down to a single-photon shot. This allows us to drive the system into a fully controllable final magnetic state of nanoscale bits. We further characterize the efficiency of the process as a function of laser fluence, and find that heat accumulation is the driving mechanism responsible for the switching.

MA 21.98 Tue 9:30 Poster A

Low frequency noise in TMR based vortex spin torque nano-oscillators — •Steffen Wittrock[1], Kay Yakushiji[2], Akio Fukushima[2], Hitoshi Kubota[2], Shinji Yuasa[2], Paolo Bortolotti[1], Enrico Rubiola[3], and Vincent Cros[1] — [1]Unité Mixte de Physique CNRS/Thales, Univ. Paris-Sud, 91767 Palaiseau, France — [2]National Institute of Advanced Industrial Science and Technology (AIST), Spintronics Research Center, Tsukuba, Ibaraki 305-8568, Japan — [3]Time-Frequency department, CNRS FEMTO-ST, Université de Franche Comté, 25030 Besançon, France

With their very rich static and dynamical properties, magnetic vortex dynamics excited by a spin polarized current represent not only a model system to study the physical mechanisms of spin transfer phenomena but could also give birth to a new generation of multifunctional microwave spintronic devices. The key property of spin-torque nano-oscillators (STNOs) is their high nonlinearity which gives rise to manifold phenomena as well as to their relatively poor spectral coherence and coupled noise behavior. While the noise distribution for offset frequencies far from the carrier frequency is reasonably well understood and described by the general nonlinear autooscillator theory, low frequency noise remains under investigation as it limits the frequency stability of the oscillator. Extensively studied in GMR and TMR sensors, this work addresses the low frequency noise of a TMR-based spin-torque vortex oscillator. We investigate the noise dependence on the active magnetic volume of the oscillation under various field and current conditions as well as its link to nonlinearity.

MA 21.99 Tue 9:30 Poster A

Torque-detected electron spin resonance and torque magnetometry — •Alexey Alfonsov[1], Vladislav Kataev[1], and Bernd Büchner[1,2] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, IFW Dresden, D-01171 Dresden, Germany — [2]Technische Universität Dresden, D-01062 Dresden, Germany

Magnetic anisotropy is a key property of many materials, which has been under a great interest of scientists from around the world. The magnetic anisotropy is defined by the complex interplay of different degrees of freedom, such as spin or/and orbital moments, charge and lattice. One of the most appropriate methods to study magnetic anisotropies, and related properties is high field and multifrequency electron spin resonance (HF-ESR), complemented by a torque magnetometry. Unfortunately samples of many new materials interesting for the investigation are available in very small sizes: in some cases it is complicated to synthesize large crystals, in other cases, the size is a key property of the material itself. This all rises a problem of the detection of the ESR signal from such a small sample, especially in the case of a multifrequency ESR spectrometer, where in order to increase the sensitivity one has to apply restrictions on the microwave frequency, strength and orientation of magnetic field. To overcome this problem we develope a multifrequency cantilever-based (torque-detected) ESR spectrometer, which is capable to perform torque magnetometry measurememnts as well.

MA 21.100 Tue 9:30 Poster A

Ab initio characterisation of skyrmion induced effects in MTJs — •Jonas Friedrich Schaefer, Michael Czerner, and Christian Heiliger — Institut für theoretische Physik, Justus-

Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen

Since interfaces and stacked layers offer a great variety of suitable systems for skyrmions, a deeper understanding of non-collinear effects in these surroundings becomes desirable. Using our KKR Code and the therein implemented Keldysh formalism we investigate the electronic transport properties of such systems with and without self-consistency. We show that this effort is necessary in order to get accurate results and to reveal the underlying physics.

MA 21.101 Tue 9:30 Poster A

In-Operando HAXPES Band Alignment Studies Of Complex Oxide Heterostructures: Au/$NiFe_2O_4$/$SrTiO_3$ — •Ronja Anika Heinen[1], Mai H. A. Hamed[1], Patrick Lömker[1], Andrei Gloskovskii[2], Wolfgang Drube[2], and Martina Müller[3] — [1]Forschungszentrum Jülich GmbH, PGI-6, Jülich — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg — [3]Technische Universität Dortmund, Experimentelle Physik I, Dortmund

Transition metal (TM) oxides exhibit a variety of physical properties due to their high tunability of spin, orbital and charge degrees of freedom. The initial way to tailor these properties is a precisely controlled growth process of single-crystalline thin film heterostructures. Thus, not only the intrinsic physical properties of the complex oxides but also the electronic conditions at the interface of functional multilayers can give raise to new paths for future applications.

In our experiments, we investigate ultrathin films of the ferrimagnetic inverse spinel $NiFe_2O_4$ (NFO) grown on the perovskite $SrTiO_3$ (STO) substrates. We use in-operando hard X-ray photoelectron spectroscopy at a photon energy of E= 6000 eV and apply in-situ bias voltages of up to U= ± 8 V in order to analyse the the chemical fingerprints and simultaneously the potential barrier profile of Au/NFO/STO heterostructures. The results provide insight into the interfacial band arrangement and bias-dependent chemical reactions of ultrathin TM oxides on a microscopic scale.

MA 21.102 Tue 9:30 Poster A

Spin transport through a contacted Heisenberg chain — •Florian Lange, Satoshi Ejima, and Holger Fehske — Institut für Physik, Ernst-Moritz-Arndt Universität Greifswald, D-17489 Greifswald, Germany

We use the density-matrix renormalization group and time-evolving block decimation algorithms to simulate the spin transport through a short Heisenberg spin chain sandwiched between two noninteracting leads under a spin bias. By using total system sizes up to 200 sites, we can accurately estimate the spin current in the steady state. The dependence of the current-voltage characteristic on the chain length and exchange anisotropy is examined. For the spin-1/2 XXZ chain, we find an activated behavior similar to the charge transport through a Mott-insulating Hubbard chain. In the high spin-voltage regime, a negative differential conductivity due to the finite band width of the leads is observed.

MA 21.103 Tue 9:30 Poster A

Hard X-ray spectroscopy of magnetic thin films for spintronic devices — •Andrei Gloskovskii[1], Gerhard H. Fecher[2], and Wolfgang Drube[1] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg — [2]Max Planck Institute for Chemical Physics of Solids, Dresden

High tunnel magneto-resistance is a characteristic of high quality magnetic tunnel junctions (MTJs) indicating a high spin polarization and epitaxial interfaces. We have studied the electronic properties of buried thin films promising as base electrodes for MTJs. In particular, the influence of the stoichiometry and annealing on the shape of the core levels and the valence band was investigated.

The main method used is Hard X-ray Photoelectron Spectroscopy where the excitation by hard X-rays in the range of typically 3-10 keV produces energetic photoelectrons which carry electronic structure information from well below the sample surface (10-30 nm) making it a powerful tool for studies of complex materials, buried nano-structures and multi-layered structures relevant for device applications. The experiments were carried out at PETRA beamline P09.

MA 21.104 Tue 9:30 Poster A

ALD growth of Fe_2O_3 thin films using Ferrocene and Ozone as precursors — •Michaela Lammel[1,2], Andy Thomas[1], and Kornelius Nielsch[1,2,3] — [1]Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden), Institute for Metallic Materials, 01069 Dresden, Germany — [2]Technische Universität Dresden, Institute of Applied Physics, 01062 Dresden, Germany — [3]Technische Universität Dresden, Institute of Materials Science, 01062 Dresden, Germany

Antiferromagnetic spintronics is currently one of the main research topics in magnetism due to the robustness of antiferromagnets against disturbances by external fields. Fe_2O_3 is a promising material system to study the magnetization dynamics in antiferromagnets. Fe_2O_3 exists mainly in two phases: antiferromagnetic α- and ferrimagnetic γ-Fe_2O_3.

We fabricate Fe_2O_3 thin films on Si/SiO_2 substrates by atomic layer deposition (ALD) using ferrocene and ozone as precursors. X-ray reflectometry was used to extract the thickness of the Fe_2O_3 films. Furthermore, the composition of the films was determined by EDX measurements. In our studies, we identified the best parameters to maximize the growth rate per cycle. In a next step, the attention will first be focused on the growth of phase-pure α- and γ-Fe_2O_3. Afterwards, we plan to perform a reduction of the Fe_2O_3 thin films into ferromagnetic Fe_3O_4 as already reported in Ref. [1]. Using ALD not only allows us to deposit thin films, but it also enables us to get conformal coatings of 3D-templates with magnetic materials.

[1] Zierold *et al.*, Journal of Physics D, Vol 47, 485001 (2014)

MA 21.105 Tue 9:30 Poster A

Spin pumping through Fe_3O_4 nano–oxide at the Fe/Pt interface — •Laura Mihalceanu, Sascha Keller, Andrés Conca, Burkard Hillebrands, and Evangelos Th. Papaioannou — TU Kaiserslautern, Erwin-Schrödinger Str. 56, 67663 Kaiserslautern

The spin current generation via spin pumping is a prominent method for the establishment of potential spin-current-generating devices. An indirect detection of this effect is provided by measuring the inverse spin Hall effect (ISHE) voltage. Various experiments have been performed in order to probe the interface properties of such bilayer systems by inserting different insulating interlayers at the FM–NM interface. Some examples are Py/MgO/Pt, $Y_5Fe_5O_{12}$/insulating barrier (Sr_2GaTaO_6,$SrTiO_3$, Sr_2CrNbO_6)/Pt structures and Fe/MgO/Pt. In our previous work on Fe/MgO/Pt we have shown the impact of an MgO tunneling barrier on the spin-pumping effect: spin currents are still inducing an ISHE voltage for very thin MgO tunneling barriers. Here, we reveal the impact of nanosized Fe_3O_4 particles at the interface of thin epitaxial Fe(12 nm)/Pt(10 nm) layers.

We show that Fe_3O_4 nanoparticles at the Fe/Pt interface significantly increase the fourfold anisotropy compared to a pure Fe/Al reference. In FMR and spin-pumping experiments a very broad linewidth of the FMR peak is revealed. The voltage generated by spin pumping is steadily detectable over a wide external magnetic field range ΔH.

In collaboration with T. Kehagias, Department of Physics, Aristotle University of Thessaloniki, Thessaloniki 54124, Greece

MA 21.106 Tue 9:30 Poster A

Interplay between localization and magnetism in (Ga,Mn)As and (In,Mn)As — Ye Yuan[1,2], Chi Xu[1,2], René Hübner[1], Rafal Jakiela[3], Roman Böttger[1], Manfred Helm[1,2], Maciej Sawicki[3], Tomasz Dietl[3,4,5], and •Shengqiang Zhou[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Technische Universität Dresden, Dresden, Germany — [3]Institute of Physics, Warsaw, Poland — [4]International Research Centre MagTop, Warsaw, Poland — [5]WPI-Advanced Institute for Materials Research, Sendai, Japan

Ion implantation of Mn combined with pulsed laser melting is employed to obtain two representative compounds of dilute ferromagnetic semiconductors (DFSs):GaMnAs and InMnAs. In contrast to films deposited by the widely used molecular beam epitaxy, neither Mn interstitials nor As antisites are present in samples prepared by the method employed here. Under these conditions the influence of localization on the hole-mediated ferromagnetism is examined in two DFSs with a differing strength of p-d coupling. On the insulating side of the transition, ferromagnetic signatures persist to higher temperatures in InMnAs compared to GaMnAs with the same Mn concentration x. This substantiates theoretical suggestions that stronger p-d coupling results in an enhanced contribution to localization, which reduces hole-mediated ferromagnetism.

MA 21.107 Tue 9:30 Poster A

High TMR at Room Temperature in Magnetic Tunnel Junctions with Phenalenyl-molecule Tunnel Barriers — •Neha Jha[1], Christian Denker[1], Anand Paryar[2], Pavan K.

Vardhanapu[2], Heba Mohamad[1], Ulrike Martens[1], Christiane Helm[1], Swadhin Mandal[2], and Markus Münzenberg[1] — [1]Institut für Physik, Universität Greifswald, Germany — [2]Department of Chemical Sciences, IISER, Kolkata, India

Phenalenyl (PLY) based molecules, which can be regarded as Graphene fragments are promising candidates for spintronic applications. Attempts to use open shell PLY molecules have been unsuccessful due to their instability. We investigated a new closed shell molecule, PLY with a Copper complex, for its spintronics suitability. TMR in various samples of PLY-Cu MTJs was determined by measuring the resistance across the MTJ under a high magnetic field during parallel and antiparallel configurations of the ferromagnets (FMs). Preliminary results show outstanding Magnetoresistance (MR) at room temperature. Our works demonstrate convincingly that spin-polarized currents can be injected into organic materials with reasonably high efficiency, providing strong evidence of spin polarized tunneling as the dominant transport mechanism in PLY-Cu based magnetic tunnel junctions, and the use of PLY-based molecules as a viable and scalable platform for building molecular-scale quantum spin memory and processors for technological development.

MA 21.108 Tue 9:30 Poster A

Magnetocaloric effect of magnetic molecules with single-ion-anisotropy — •Julian Ehrens, Christian Beckmann, and Jürgen Schnack — Universität Bielefeld, PF 100131, D-33501 Bielefeld

The magnetocaloric effect can fundamentally be described as the change of temperature when materials are exposed to changing magnetic fields in e.g. adiabatic processes. Along this line, magnetocaloric properties of isotropic spin systems, that are modeled by a Heisenberg Hamiltonian augmented with a Zeeman term, have been investigated extensively [1]. Magnetic molecules with single-ion-anisotropy such as Mn_{12}, whose ground state multiplet can be approximated as the multiplet of a single giant spin with dominating easy axis, enable the use of rotating magnetic fields or rotating samples to exploit the magnetocaloric effect. Here we report investigations being made for giant spin models with various spin quantum numbers employing several thermodynamic cycles including the successive rotation around different axes in order to find the maximum entropy difference for best cooling performance.

[1] J.W. Sharples, D. Collison, E.J.L. McInnes, J. Schnack, E. Palacios, M. Evangelisti, Nature Communications 5 (2014) 5321

MA 21.109 Tue 9:30 Poster A

Investigation of decoherence in 2-qubit systems realized as magnetic molecules — •Patrick Vorndamme and Jürgen Schnack — Universität Bielefeld, PF 100131, D-33501 Bielefeld

Magnetic molecules are considered as promising constituents of quantum simulators or quantum computers. At low temperatures the magnetic levels of molecular nanomagnets enable the use as qubits. For such an application the investigation and understanding of decoherence caused by external and internal effects is very important. Here we aim at a better understanding of the diverse aspects of decoherence by investigating experimentally relevant notions of decoherence in unitary time evolutions of finite-size closed systems of interacting electronic as well as nuclear spins. We examine the behavior of the qubits and related observables as a function of the considered interactions (SU(2) symmetric or dipolar) and the properties of the nuclear spin bath.

MA 21.110 Tue 9:30 Poster A

Fundamental thermodynamic processes investigated for anisotropic magnetic molecules — •Christian Beckmann and Jürgen Schnack — Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld

The theoretical understanding of time-dependence in magnetic quantum systems is of great importance in particular for cases where a unitary time evolution is accompanied by relaxation processes. This is of special interest for the realization of fundamental thermodynamic processes.

In this contribution we investigate how fundamental thermodynamic processes, such as Carnot, Otto or Stirling, can be performed with finite velocity on an anisotropic magnetic molecule by rotation of the applied magnetic field.

MA 21.111 Tue 9:30 Poster A

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

We present ^{57}Fe Mössbauer studies on large single crystals of diluted Fe ions in $Li_2(Li_{1-x}Fe_x)N$ which forms a hexagonal symmetric α-Li_3N crystal matrix. The homogeneity of the nanoscale distributed isolated Fe centers is shown. The isolated Fe centers, e.g. for $x = 2.5(1)\%$, exhibit a giant magnetic hyperfine field of $B = 70.22(1)$ T parallel to the largest principle axis $V_{zz} = -154.10(19)$ V/Å^2 of the electric field gradient at 2 K, same for other $x \ll 1$. The magnetic hyperfine field fluctuates between 50 K and 300 K probed by Mössbauer spectroscopy described by a two-level relaxation model. The spin dynamics is similar to a behavior known from single-molecule magnets. An Arrhenius frequency plot $\nu = \nu_0 e^{-E_A/k_B T}$ yields a thermal activation barrier of $E_A = 542(8)$ K and $\nu_0 = 216(22)$ GHz which consistent with magnetization investigations. An applied transverse magnetic field study up to 5 T at 70 K shows a sensitivity two orders of magnitude higher than expected from the conventional theory of nanomagnets.

MA 21.112 Tue 9:30 Poster A

Chemical doping of Fe_4 single molecule magnets on surfaces — •Vivien Enenkel, Fabian Paschke, Philipp Erler, Luca Gragnaniello, and Mikhail Fonin — Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany

Single molecules magnets are promising candidates for future applications in the field of molecular spintronics or ultra-dense information storage. Here we investigate the effect of chemical doping by alkali metals on Fe_4H molecules on graphene/Ir(111) and Au(111) surfaces. Submonolayers of intact Fe_4H molecules in form of close-packed islands are prepared on surfaces via the electrospray ionization method [1,2]. The subsequent deposition of dopant atoms (Li, Na) leads to appearance of a new molecular configuration appearing bright and slightly asymmetric compared to the rest of the molecules. We assume that in this configuration a dopant atom resides on the Fe_4H molecule, which leads to the direct electron transfer from Li (Na) to one of the Fe atoms. STS spectra on doped species show a shift in the energetic positions of molecular orbitals as well as further electronic states emerging in the conduction gap as compared to undoped molecules. By means of x-ray absorption spectroscopy, we observe that doping leads to substantial changes in the line shape of the Fe L-edge indicating the reduction of Fe^{3+} to Fe^{2+} in the molecular core.

[1] P. Erler et al., Nano Lett. 15, 4546 (2015). [2] L. Gragnaniello et al., Nano Lett., 2017, in press.

MA 21.113 Tue 9:30 Poster A

Element-selective magnetic properties of mixed 3d - 4f metallacrowns — •Ahmed Alhassanat[1], Alexey A. Sapozhnik[1], Christoph Gamer[2], Angeliki Athanasopoulou[2], Lara Völker[2], Chen Luo[3], Hanjo Ryll[3], Florin Radu[3], Eva Rentschler[2], and Hans-Joachim Elmers[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]Institut für Anorganische und Analytische Chemie, Johannes Gutenberg-Universität Mainz — [3]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin

Single molecular magnets comprising rare earth metals are of high interest because the unquenched orbital moments of the rare earth ions result in a large energy barrier for magnetization reversal. We investigate polynuclear $4f$ - $3d$ metallacrowns using X-ray magnetic circular dichroism at low temperatures. The element-selective spin and orbital moments of the rare earth ions hint to a large magnetic anisotropy of up to 6 meV. The magnetic moments of some $3d$ transition metal ions can be controlled by chemical means upon changing the corresponding ligand field.

MA 21.114 Tue 9:30 Poster A

High-frequency AC susceptometry on Lanthanide-containing molecular magnets — •Léo de Souza, Krunoslav Prsa, and Oliver Waldmann — Physikalisches Institut, Universität Freiburg, Germany

We present details on the adaptation of a high-frequency (f_{max} = 100 kHz) AC-susceptometer. Lanthanide-based molecular magnets display fast relaxation rates and in order to distinguish between different involved mechanisms it is necessary to use a large frequency range. We describe the steps taken to improve the existing home-made AC-setup towards reliable routine operation. A key aspect is calibration, especially the treatment of phase shifts. We show measurements done over a large span of frequencies and temperatures on a known paramagnetic sample used as a calibration standard and discuss the developed calibration techniques. In addition, preliminary results on a mixed transition metal-lanthanide molecular magnet are presented.

MA 22: Focus Session: Magnetism in Materials Science: Thermodynamics, Kinetics and Defects III (joint session MM/MA)

Magnetism V

Time: Tuesday 11:45–13:00 Location: H 0106

Topical Talk MA 22.1 Tue 11:45 H 0106

Grain boundary migration and grain growth in non-ferromagnetic metals under the impact of a magnetic field — •Dmitri A. Molodov — Institute of Physical Metallurgy and Metal Physics, RWTH Aachen University, 52056 Aachen, Germany

Grain boundary migration can be induced by a magnetic field, if the anisotropy of the magnetic susceptibility generates a gradient of the magnetic free energy density across the boundary. In contrast to curvature driven boundary motion, a magnetic driving force also acts on planar boundaries so that the motion of crystallographically fully defined boundaries can be investigated. The magnetically driven motion of planar symmetric and asymmetric tilt grain boundaries was studied in high purity bismuth and zinc bicrystals. Boundary migration was measured in-situ by means of a polarization microscopy probe and the corresponding migration activation parameters were obtained. The results revealed that grain boundary mobility essentially depends on the misorientation angle and the inclination of the boundary plane.

As it has been demonstrated in a series of experiments on polycrystalline zinc, titanium and zirconium, as well as by computer simulations, grain growth in magnetically anisotropic non-ferromagnetic materials can be substantially affected by a magnetic field. This manifested itself by significant changes in the development of the grain growth texture during magnetic annealing compared to annealing at zero field. The magnetically induced texture changes are caused by the generation of an additional magnetic driving force for grain growth/shrinkage.

MA 22.2 Tue 12:15 H 0106

Stability and magnetic properties of grain boundaries in the inverse Heusler phase Fe_2CoGa and in bcc Fe — •Daniel F. Urban[1], Wolfgang Körner[1], Georg Krugel[1], Anna Lehner[1], and Christian Elsässer[1,2] — [1]Fraunhofer IWM, Freiburg, Germany — [2]University of Freiburg, FMF, Germany

Grain boundaries (GBs) in the cubic inverse Heusler phase Fe_2CoGa are investigated by means of first principles calculations based on density functional theory. The results are compared to those of corresponding GBs in bcc Fe. Besides the energetic stability, the analysis focuses on the magnetic properties of the GBs. The inverse Heusler phase offers a variety of interesting low energy GBs. It is found that such GBs do not lead to a breakdown of the local magnetic moments at the interface, as observed for some of the GBs in bcc Fe. Instead there is partially even a substantial enhancement near the GB. Nevertheless, the integrated increase in total magnetic moment is very similar for GBs in both materials. The analysis of the ferromagnetic coupling indicates that the coupling across such low energy interfaces is not reduced with respect to the single crystal of Fe_2CoGa, whereas in bcc Fe a weakening or even decoupling of two grains can occur.

MA 22.3 Tue 12:30 H 0106

Magnetic properties of the CrMnFeCoNi high-entropy alloy — Oldřich Schneeweiss[1], •Martin Friák[1,2], Marie Dudová[1], David Holec[3], Mojmír Šob[2,1,4], Dominik Kriegner[5], Václav Holý[5], Přemysl Beran[6], Easo-P. George[7], Jörg Neugebauer[8], and Antonín Dlouhý[1] — [1]Institute of Physics of Materials, Academy of Sciences of the Czech Republic, Brno, Czech Republic — [2]Central European Institute of Technology, CEITEC MU, Masaryk University, Brno, Czech Republic — [3]Department of Physical Metallurgy and Materials Testing, Montanuniversitaet Leoben, Leoben, Austria — [4]Department of Chemistry, Faculty of Science, Masaryk University, Brno, Czech Republic — [5]Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic — [6]Nuclear Physics Institute, Academy of Sciences of the Czech Republic, Řež, Husinec, Czech Republic — [7]Institute for Materials, Ruhr University, Bochum, Germany — [8]Max-Planck-Institut für Eisenforschung GmbH, Düsseldorf, Germany

The equiatomic CrMnFeCoNi high-entropy alloy undergoes a paramagnetic-to-spin-glass transition at 93 K and a ferromagnetic transition at 38 K while maintaining its fcc structure down to 3 K (Phys. Rev. B 96 (2017) 014437). We study the local atomic magnetic moments in this material by *ab initio* calculations. We find the Cr magnetic moments aligning antiferromagnetically with respect to a cumulative magnetic moment of their first coordination shell. The magnetic moments of Fe and Mn atoms remain high (between 1.5 and 2 μ_B), while the local moments of Ni atoms effectively vanish.

MA 22.4 Tue 12:45 H 0106

Effect of magnetic transition on grain boundary diffusion of Mn in α-iron — Vladislav Kulitckii, Sergiy Divinski, and •Gerhard Wilde — Institut für Materialphysik, Westfälische Wilhelms-Universität Münster, Münster, Germany

Grain boundary diffusion of Mn in α-Fe has been studied in both, B- and C-types kinetic regimes in a wide temperature range of 473 to 1173 K. The concentration profiles were measured applying the radiotracer technique with serial sectioning by microtome and using the 54Mn radioactive isotope. As a result, Mn segregation at general high-angle grain boundaries of *-Fe is estimated. The grain boundary diffusivities were found to exhibit a distinct non-linear Arrhenius temperature dependence that in discussed in terms of the impact of the magnetic transition on Mn grain boundary diffusion.

MA 23: Non-ultrafast magnetization dynamics

Time: Wednesday 9:30–12:30 Location: H 0112

MA 23.1 Wed 9:30 H 0112

Quantitative comparison of different methods for the Gilbert damping in clean ferromagnets. — •Jens Renè Suckert, Filipe Souza Mendes Guimarães, Jonathan Chico, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The Gilbert damping constant describes relaxation in magnetic systems. Efforts to describe the damping from first principles have been made for almost 50 years [1]. A multitude of approaches to calculate the damping have been proposed since then [1,2,3]. Still, a disparity between theoretical and experimental descriptions at low temperatures [3] and between different theoretical approaches persists. In particular, the behaviour of clean ferromagnets at low temperatures is still debated [4]. In this work, we present calculations of the damping constant for clean Fe, Ni and Co bulk systems using a unified framework based on a multi-orbital tight-binding model to investigate the different approaches and resolve the disparity at low temperatures.
This work is supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator grant 681405 – DYNASORE).
[1] V. Kamberský, Czech J. Phys. 26, 1366 (1976).
[2] A. Brataas, et *al.*, Phys. Rev. Lett. 101, 037207 (2008).
[3] S. Mankovsky et *al.*, Phys. Rev. B 87, 014430 (2013).
[4] D.M. Edwards, J. Phys.: Condens. Matter 28, 086004 (2016).

MA 23.2 Wed 9:45 H 0112

Local spin-wave dispersion and damping in thin yttrium iron garnet films — •Rouven Dreyer[1], Niklas Liebing[1], Eric R. J. Edwards[1,2], and Georg Woltersdorf[1] — [1]Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany — [2]National Institute of Standards and Technology Boulder, CO, U.S.A.

By time-resolved magneto-optic imaging we investigate the spin-wave dispersion and spin-wave damping in yttrium iron garnet thin film samples with a thickness of 200 nm. Using the inhomogeneous magnetic field generated by a coplanar waveguide spin waves are excited at a fixed frequency while the wavelength is tuned by the external magnetic field. By imaging the excited spin waves with a scanning time-resolved MOKE setup and mapping their dispersion we identify a method to determine the damping of the homogeneous mode locally. Furthermore we find that in the vicinity of avoided crossings in the spin-wave dispersion the group velocity of excited spin waves is close to zero. Here we are able to extract the Gilbert damping parameter for localized spin waves. The obtained values are in good agreement with the results for the uniform mode. In comparison to inductive FMR measurements we find narrower linewidths for the uniform mode due to the local character of our measurements.

MA 23.3 Wed 10:00 H 0112

Analysis of magnetoelastic coupling in Co-Pt multilayer systems — •Norbert Weinkauf[1], Peter Gaal[1], Raanan Tobey[2], Chia-Lin Chang[2], and Hans Peter Oepen[1] — [1]Institute of Nanostructure and Solid State Physics, University of Hamburg, Germany — [2]Faculty of Science and Engineering, University of Groningen, the Netherlands

We have measured optically excited magnetization precession on thin, in-plane Co-Pt multilayer systems on glass substrate. Using a three-temperature model the fast energy transfer from the electron and spin system to the lattice few picoseconds after optical excitation is explained. The initial lattice temperature after excitation is significantly lower than the Curie temperature of Cobalt. Hence we assume that demagnetization and the subsequent precession is instantly driven by shear strain and not heat. In addition we derive a quantitative model by the analytical solution of the Landau-Lifshitz equation.

Furthermore we use transient grating excitation on the same cobalt multilayers. The time-resolved measurement of Faraday rotation and of the diffraction from the transient grating yields information about the magnetoelastic coupling. Two distinct resonances were detected, one assigned to a surface acoustic wave, one to surface skimming longitudinal wave. These can be calculated by a parametric oscillator model and the Landau-Lifshitz equation.

In addition, similar measurements were performed for Co-Pt multilayer systems on 500nm SiNi-membranes. We observe distinct differences in the acoustic mode spectrum compared to bulk substrates.

MA 23.4 Wed 10:15 H 0112

Fabrication and Characterization of individual sub-100 nm YIG Structures using Brillouin Light Scattering Microscopy — •Björn Heinz[1], Thomas Brächer[1], Michael Schneider[1], Philipp Pirro[1], Bert Lägel[1], Carsten Dubs[2], Oleksii Surzhenko[2], and Andrii V. Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]INNOVENT e.V., Technologieentwicklung Jena, 07745 Jena, Germany

Yttrium-iron-garnet (YIG) is a unique material with outstanding magnetic properties such as the lowest known spin-wave damping. It is therefore well suited for the investigation of fundamental spin-wave dynamics and a promising candidate for the application in magnonic circuits and logic devices. In this work, we study the impact of micro- and nanostructuring by means of electron beam lithography and successive ion milling on individual spin-wave waveguides. These structures are fabricated from a 41 nm thin film grown by liquid phase epitaxy (LPE). Their width varies from a few microns down to the sub-100 nm regime. By exciting the magnetization dynamics with a microwave field and performing time resolved Brillouin light scattering (BLS) microscopy measurements we investigate the influence of the structuring process on the magnon lifetime. Additionally the spin-wave mode spectra are extracted by means of thermal BLS measurements. This research has been supported by ERC Starting Grant 678309 MagnonCircuits and DFG Grant DU 1427/2-1.

MA 23.5 Wed 10:30 H 0112

Ferromagnetic resonance in superconductor/ferromagnet bilayers — •David Sanchez-Manzano[1], Myoung-Woo Yoo[2], Hiroshi Naganuma[2,3], Pierre Mergny[2], Abdelmadjid Anane[2], Jacobo Santamaria[1], and Javier E. Villegas[2] — [1]GFMC , Dpto F. Materiales, University Complutense of Madrid (Spain) — [2]CNRS -Thales, Unité Mixte de Physique, Palaiseau (France) — [3]Department of Applied Physics, Tokyo University of Science, 1-3, Kagurazaka, Shinjuku-ku, Tokyo (Japan)

We study the superconductor/ferromagnet proximity effect via ferromagnetic resonance (FMR) [1] in S/F bilayers that combine the high-temperature superconductor YBa2Cu3O7 with different ferromagnets, either Permalloy (NiFe) or the half-metallic La0.7Sr0.3MnO3. We compare the results of this bilayers to reference ferromagnetic single layers to observe how the presence of the superconductor layer affects the FMR signal. The FMR linewidth is studied as a function of temperature (10K-293K) and frequency (up to 20 G Hz) to obtain the damping constant (α) above and below the superconducting critical temperature. The results will be discussed in the frame of the spin-pumping theory considering the superconductor a spin sink where part of the FMR generated angular momentum relaxes in the superconductor through spin-pumping. [2].

[1] Bells, C., Aarts, J. et al. Phys. Rev. Lett. 100 047002 (2008) [2] Yokoyama, T. & Tserkovnyak, Y. Phys. Rev. B 80, 104416 (2009)

Work supported by the ERC grant N 64710 and French ANR grant ANR-15- CE24- 0008-01

MA 23.6 Wed 10:45 H 0112

Influence of substrate doping on Spin Pumping — •Babli Bhagat, Tanja Strusch, Michael Farle, and Florian M Römer — Faculty of Physics and Center for Nanointegration (CENIDE), University of Duisburg-Essen, Lotharstr. 1, 47057, Duisburg, Germany

Spin Pumping into semiconductor has a technical as well as fundamental relevance for spintronic devices. The magnetic damping of a Ferromagnet/Semiconductor heterostructure should be influenced by the conductivity and other properties of the semiconductor.

We have studied magnetic damping in Pt/Ag/Fe/GaAs(110) epitaxial heterostructures with different doping of GaAs (undoped, n-doped, and p-doped) by Ferromagnetic Resonance measurements (FMR). Samples were prepared using electron beam evaporation at $< 8*10^{-8}$ Pa at the rate of ~1Å/minute. Low Energy Electron Diffraction (LEED) was done before and after depositing epitaxial Fe film on

GaAs. Ex situ FMR from 1-40GHz was performed in three different crystallographic directions namely easy <100>, hard <111> and intermediate <110> in plane direction of the film. Also angle dependent FMR at ∼13GHz were performed. The Gilbert-Damping parameter α and anisotropic constants were calculated by fitting frequency dependent and angle dependent lineshape respectively. We observed different damping behaviour at different directions of the film. With respect to undoped sample there is ∼15% increase in α in hard <111> direction in p-doped sample while ∼12% increase in <110> direction. In easy direction there is instead ∼28% decrease of damping parameter with undoped sample in p-doped GaAs.

MA 23.7 Wed 11:00 H 0112

Simulation of hot-electron spin currents in magnetic multilayers — Dennis M. Nenno[1,2], Marius Weber Weber[1], Rolf Binder[2], and •Hans Christian Schneider[1] — [1]University of Kaiserslautern, Kaiserslautern, Germany — [2]University of Arizona, Tucson, USA

“Hot electron” spin-currents in magnetic heterostructures, which result from excitation by ultrafast optical pulses, have been described by different non-diffusive electron-transport calculations [1,2]. We present a computational approach to hot-electron transport in magnetic multilayers based on the particle-in-cell method for the Boltzmann transport equation. This approach allows one to simulate the electronic dynamics in the whole slab, including transmission coefficients and ab-initio material data. From the calculations, we extract typical transport coefficients and clarify the contribution of secondary carrier generation in the transition from ballistic to diffusive transport behavior.

We combine our transport model with a calculation of the emitted fields to determine the radiation spectrum from spintronic Terahertz emitters [3], and analyze both single emitters and arrays.

[1] M. Battiato et al., Phys. Rev. B 86, 024404 (2012).
[2] D. M. Nenno et al., Phys. Rev. B 94, 115102 (2016).
[3] T. Seifert et al., Nature Photonics 10, 483 (2016).

15 minutes break

MA 23.8 Wed 11:30 H 0112

Dynamic nuclear polarization with single shallow NV center in diamond — •Farida Shagieva, Andrej Denisenko, Philipp Neumann, and Jörg Wrachtrup — 3rd Institute of Physics, University of Stuttgart, Stuttgart, Germany

Nuclear magnetic resonance (NMR) is one of the most powerful techniques used in physics and life sciences. The latest developments in this area are directed to make high-resolution NMR systems that are smaller, cheaper, more robust and portable than the existing ones. Recently, the shallow nitrogen-vacancy centres in diamond started to be used for nanoscale NMR imaging and spectroscopy of nuclear species under ambient conditions [1]. These multifunctional quantum sensors provide the noninvasive methods to get the chemical composition [2] of the molecules and to study the system dynamics within the nanoscopic volume above the diamond surface. Despite a remarkable progress in this area, potential applications are often limited by low sensitivity. Hyperpolarisation techniques have the potential to overcome this limitation and revolutionise the use of compact NMR. Several techniques to realise the (DNP) dynamic nuclear polarization using NV centres have been demonstrated for internal diamond spins [3-4]. The goal of this study is to perform a hyperpolarization of external for diamond solid spins and demonstrate an improvement of the NMR signal.

[1] T. Staudacher et al., Science 339, 561 (2013).
[2] N. Aslam et al., Science 357, 67 (2017).
[3] P. London et al., PRL 111, 067601 (2013).
[4] F. Poggiali et al., Phys. Rev. B 95, 195308 (2017).

MA 23.9 Wed 11:45 H 0112

Time-resolved magneto-optical investigation of Surface Acoustic Wave sensors (SAW) — •Cai Müller, Anne Kittmann, Phillip Durdaut, Benjamin Spetzler, Sebastian Zabel, Rasmus B. Holländer, Michael Höft, Franz Faupel, Eckhard Quandt, and Jeffrey McCord — Institute for Materials Science, Kiel University, Kiel, Germany

Surface acoustic waves (SAW) delay lines and resonators can be tuned via magnetostrictive layers and application of an external magnetic field by magnon-phonon interactions [1]. This mechanism enables magnetic field sensing. Knowledge of the local magnetization structure during the SAW excitation helps to understand the exact magnetic origin of the SAW-modulation. Here investigations of the magnetodynamic response of a thin FeCoSiB film on a quartz substrate by time-resolved magneto-optical wide-field imaging are presented. The method enables direct measurements of the wave velocity. The data suggests a strong magnetization response of domain walls to the local effective field generated by the SAW.

[1] Smole, P. et al., IEEE International Frequency Control Symposium and PDA Exhibition Jointly with the 17th European Frequency and Time Forum, 2003, p. 903-906 (2003)

MA 23.10 Wed 12:00 H 0112

Coupling between vortices and antivortices in a cross-tie wall studied by time-resolved SEMPA — •Fabian Kloodt-Twesten, Susanne Kuhrau, Philipp Staeck, Hans Peter Oepen, and Robert Frömter — Center for Hybrid Nanostructures, Universität Hamburg, Germany

In the framework of the Thiele equation magnetic vortices and antivortices can be treated as quasiparticles. Confining a single (anti-)vortex in a magnetic microstructure causes linear restoring forces, which results in an oscillator equation describing the field-driven motion of individual solitons. Using TR-SEMPA [1] we investigate the coupling of magnetic vortices and antivortices in a cross-tie wall in rectangular FeCoSiB-structures. While the vortices exhibit a clear oscillation the antivortices show almost no discernible movement. Both types of magnetic solitons are mutually coupled via the domain energy (part of the stray-field energy), resulting in a coupled oscillation mode under HF-field excitation. TR-SEMPA results and micromagnetic simulations show an excellent agreement indicating that the boundary condition in the sample together with a strong coupling between both solitons is the driving mechanism of the observed behavior. The motion is composed from the contributions of two terminating vortices and a mutual vortex-antivortex coupling along the confined cross-tie structure.

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

MA 23.11 Wed 12:15 H 0112

Electric field control of gyration dynamics of magnetic vortices — •Mariia Filianina[1,2], Lorenzo Baldrati[1], Tetsuya Hajiri[3], and Mathias Kläui[1,2] — [1]Mainz University, 55128 Mainz, Germany — [2]Graduate School of Excellence MAINZ, 55128 Mainz, Germany. — [3]Nagoya University, 464-8603 Nagoya, Japan.

Energy-efficient control of magnetism is fundamental for the development of spintronic devices. This is enabled for instance by the electric field control of the magnetization, as can be done in multiferroic materials [1]. Significantly large magneto-elastic effect (ME), i.e. tuning the magnetic anisotropy by strain, can be induced by an electric field in magnetic thin films grown on piezoelectric substrates [2-5]. While the quasi-static behavior of the ME effect has been thoroughly analyzed, there are only a few experimental studies of the effect of ME coupling on the dynamical behavior of the magnetization [4,5].

Here we report on the electric field control of magnetic vortex core gyration dynamics via ME effect in magnetostrictive microstructures fabricated on top of a piezoelectric substrate. Piezoelectric strain modifies the anisotropy and thus the vortex gyration trajectories which we image by means of time-resolved XMCD-PEEM. A comparison with micromagnetic simulations is presented to quantitatively assess the dynamical effect resulting from the ME coupling.

1. N.A. Spaldin and M. Fiebig, Science 309, 391 (2005). 2. J.G. Wan et al., Appl. Phys. Lett. 88, 182502 (2006). 3. S. Finizio et al., Phys. Rev. Appl. 1, 021001 (2014). 4. M. Foerster et al., Nat. Commun. 8, 407 (2017). 5. S. Finizio et al., Phys. Rev. B 96, 054438 (2017).

MA 24: Focus Session: Exploiting spintronics for unconventional computing (joint session MA/TT)

Over the past century, the miniaturization of electronics has improved commensurately to the growth in computational power following an empirical relationship known as "Moore's law", an observation that microprocessor performance doubles every 18 months. It has now become clear that this trend will unlikely continue in the future due to limits both in the downscaling of transistors as well as the fundamental throughput of data between CPU and memory elements in traditional Von Neumann computer architectures. A completely new path forward has however been offered by bioinspired approaches to computation which attempt to capture the intrinsic parallelism and energy efficiency exhibited by the animal brain. The past two decades have in fact seen the flourishing of digital machine learning and deep neural network techniques to process data intensive tasks ranging from image recognition to AI development. The next frontier will consist of further optimizing these approaches by designing physical devices capable of implementing these functional principles analogically. Advances in nanomagnetism and spintronics have assembled a versatile toolbox of electrically controllable materials and phenomena whose applications not only integrate seamlessly within current CMOS architectures but also present a radical new horizon for the evolution of device construction and development. The goal of this focus session is to construct a comprehensive picture of the state-of-the-art of spintronic applications to unconventional computing paradigms such as Boltzmann Machines, Neural Network, Probabilistic and Reservoir Computing. The talks will bring together leading scientist in the rapidly evolving field of spintronic computing to highlight the roles that thermally susceptible magnetization dynamics, exotic magnetic textures, frustrated systems and spin waves can play in shaping the computing devices of tomorrow.

Organized by: Daniele Pinna, Karin Everschor-Sitte (U. Mainz)

Time: Wednesday 9:30–12:15 Location: H 1012

Invited Talk MA 24.1 Wed 9:30 H 1012

Control of Mesoscopic Magnetism for Computation — •Laura Heyderman — Laboratory for Mesoscopic Systems, Department of Materials, ETH Zurich, 8093 Zurich, Switzerland — Laboratory for Multiscale Materials Experiments, Paul Scherrer Institute, 5232 Villigen PSI, Switzerland

To exploit mesoscopic magnetism in computation, it is necessary to control the magnetic states with an external stimulus. In hybrid mesoscopic structures with two different ferromagnetic layers, the static and dynamic behaviour results from the mutual imprint of the magnetic domain configurations, which can be exploited to create a nanoscale switch for the magnetisation [1]. With multiferroic composites, an electric field can be used to induce uniform magnetization rotation in single domain submicron ferromagnetic islands grown on ferroelectric single crystal [2]. In artificial spin ice [3], which are arrays of coupled nanomagnets, emergent magnetic monopoles can be manipulated in a magnetic field [4]. For device applications, the additional control can be gained by modifying the anisotropy of the individual magnets. Such anisotropy engineering can also be used to control the chirality of vortex states in hexagonal rings of nanomagnets [5]. Finally, one can modify the geometry of an artificial spin ice to display dynamic chirality where the average magnetization rotates in unique sense during thermal relaxation [6]. [1] M. Buzzi et al. PRL (2013) [2] P. Wohlhüter et al. Nat. Commun. (2015) [3] L.J. Heyderman and R.L. Stamps, JPCM (2013) [4] E. Mengotti et al. Nature Phys. (2011) [5] R. Chopdekar et al. New J. Phys (2013) [6] S. Gliga et al. Nat. Mater. (2017)

MA 24.2 Wed 10:00 H 1012

Phase domain nucleation and growth investigated in nanofabricated FeRh — •Rowan Temple[1], Jamie Massey[1], Trevor Almeida[2], Kayla Fallon[2], Stephen McVitie[2], Thomas Moore[1], and Christopher Marrows[1] — [1]University of Leeds, Leeds, UK — [2]University of Glasgow, Glasgow, UK

The binary alloy FeRh with B2 (CsCl) chemical ordering displays a magnetostructural phase transition at an unusually high temperature of 350 K. Heating through this point the material undergoes an antiferromagnetic (AF) to ferromagnetic (FM) transition, this is accompanied by a 1% volume expansion in the crystal lattice. Being thermodynamically first order in nature, the transition is hysteretic with metastable states coexisting within the material close to the transition temperature. Using nanofabricated epitaxially grown films of FeRh we have examined the effects of rapid thermal heating of this material beyond its equilibrium state. We find decay into equilibrium state is exponential independent of temperature, commensurate with a purely nucleation rather than domain growth driven transition. We have further investigated size dependence of the transition through PEEM imaging and find edge nucleations are key to the transition in a patterned device and lower the expected transition temperature. This understanding will be used to enable the use of patterned FeRh for unconventional computing techniques.

Invited Talk MA 24.3 Wed 10:15 H 1012

Spin waves for unconventional computing and data processing — •Philipp Pirro, Thomas Brächer, and Andrii Chumak — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Erwin-Schrödinger-Straße 56, 67663 Kaiserslautern

Spin waves, the collective excitations of the spin lattice of a magnetic material and their quanta, magnons, show a large variety of linear and nonlinear wave phenomena. They constitute a flow of spin angular momentum which opens a new sub-field of spintronics: magnon spintronics, where information is transferred and processed using magnons including a coupling to electron-based spintronic circuits.

In my presentation, I will first review different computing approaches based on spin waves and discuss the advantages and challenges of an interference-based logic. Next, I will present a selection of the experimentally realized macroscopic prototypes for spin-wave based logic like the majority gate and the magnon transistor. A downscaling of more than three orders of magnitude of these prototypes is required to compete with conventional CMOS technology. Therefore, I will discuss new features associated with the miniaturization like strong quantization effects as well as ways to interconnect to conventional spintronic circuits. Exemplarily, I will present different nanoscopic magnonic devices which use linear and nonlinear effects like magnonic wake-up receivers and nano-transistors.

15 minutes break

Invited Talk MA 24.4 Wed 11:00 H 1012

p-bits, p-transistors and p-circuits — •Kerem Camsari — Purdue University

Conventional logic/memory devices are built out of deterministic units such as MOS transistors, or nanomagnets with energy barriers in excess of 40 kT. We show that unstable, stochastic units which we call "p-bits" can be interconnected to create correlations that implement

Boolean functions with impressive accuracy, comparable to digital circuits. They are also "invertible", a unique property that is absent in digital circuits. In the direct mode, the input is clamped, and the network provides the correct output. In the inverted mode, the output is clamped, and the network fluctuates among all possible inputs that are consistent with that output. We present an implementation of such a p-bit using existing technology. The results for this hardware implementation agree with those from a universal model for p-bits, showing that p-bits need not be magnet based: any transistor-like tunable random bit generator should be suitable. We present an algorithm for designing a bi-directional p-bit network that implements a given truth table. We then show such bi-directional units, such as Full Adders, can be interconnected in a directed manner to implement 32-bit addition, that correlate hundreds of stochastic p-bits. We also show that despite the directed interconnections, invertibility is largely preserved. This combination of digital accuracy and logical invertibility is enabled by the hybrid design using bidirectional BM units to construct circuits with directed inter-unit connections.

MA 24.5 Wed 11:30 H 1012

Thermally excited skyrmion motion for probabilistic computing — •Jakub Zázvorka[1], Daniel Heinze[1], Kai Litzius[1,2,3], Samridh Jaiswal[1,4], Sascha Kromin[1], Niklas Keil[1], and Mathias Kläui[1,4] — [1]Johannes Gutenberg University Mainz, Institute of Physics, Mainz, Germany — [2]Max Plank Institute for Intelligent Systems, Stuttgart, Germany — [3]Graduate School of Excellence "Materials Science in Mainz", Mainz, Germany — [4]Singulus Technologies AG, Kahl am Main, Germany

A key problem for probabilistic computing is that cascading gates propagate undesired correlations. Therefore, one needs to reshuffle the signals to keep them uncorrelated. While for many non-conventional computing approaches non-magnetic implementations are most promising, for building a "reshuffler", skyrmions might be ideally suited due to the low footprint and low power compared to e.g. CMOS implementations [1]. We have studied a Ta-based material where we can stabilize skyrmions and controllably nucleate and displace them by current pulses due to spin-orbit torques. We find topologically non-trivial N=1 skyrmions that move with the application of current pulses. At zero applied current, we find thermally activated skyrmion motion. We track the trajectories of skyrmions and from the dependence of their mean-square-displacement (MSD) on time, we can identify motion by diffusion and obtain the diffusion constant. There is a strong dependence of the skyrmion diffusion parameter on temperature and the skyrmion size. Finally, we patterned the reshuffler geometry and ascertain its performance. [1] D. Pinna et al., arXiv:1701.07750, 2017.

Invited Talk MA 24.6 Wed 11:45 H 1012

Bits and Brains: New materials and brain-inspired concepts for low energy information processing — •Theo Rasing — Radboud University, Nijmegen, the Netherlands

Data is the fuel of the new digital economy that has stimulated a whole new class of innovative technologies and businesses. While data has become an indispensable part of modern society, the rate at which data is generated is exploding. This is not only pushing our current technologies to their limits, but also that of our energy production: our ICT and data centers already consume around 5% of the world electricity production and with an annual increase of 7%, this is rapidly becoming unsustainable. In stark contrast, the human brain, with its intricate architecture combining both processing and storing of information, only consumes about 10 Watt of energy while having a similar capacity as a supercomputer consuming around 10 Megawatt. We have created a consortium of condensed matter, material and neuro scientists with the aim to develop materials and concepts that mimic the efficiency of the brain by combining local processing and storage, using adaptable physical interactions that can implement learning algorithms.

MA 25: Multiferroics and magnetoelectrics II (joint session MA/KFM)

Time: Wednesday 9:30–12:00 Location: EB 202

MA 25.1 Wed 9:30 EB 202

Magneto-ionic ON/OFF switching of magnetization in FeOx/Fe nanostructures — •Jonas Zehner, Kenny Duschek, Nicolas Peréz, Andreas Petr, Rudolph Schäfer, Kornelius Nielsch, and Karin Leistner — IFW Dresden

A novel route towards low-power voltage-control of magnetism was recently discovered by utilizing voltage-induced ion migration and electrochemical oxidation/reduction in oxide/metal films and denominated magneto-ionic effect [1,2,3]. In all-solid architecture, significant magneto-ionic effects are achieved at elevated temperatures when ion migration is thermally activated. Instead, we present large voltage-induced magnetic changes within several nanometers of FeOx/Fe films at room temperature. The voltage is applied via a liquid alkaline electrolyte [4] (KOH or LiOH solution), which, in comparison to solid oxide gate barrier layers, yields an enhanced electric field and a higher ion mobility at the electrode surface. Nearly complete and reversible voltage-induced ON/OFF switching of magnetization (up to 90 %) is observed in granular FeOx/Fe thin films for a voltage change of 1 V, proven by in situ AHE and in situ FMR. An in situ Kerr microscope set-up has been developed that resolves magnetic domains through a liquid alkaline electrolyte. Thereby, for the first time, the study of the local impact of electrochemical reactions on the magnetic domain characteristics becomes possible for solid/liquid magneto-ionic systems. [1] Song et al., Prog. Mater Sci. 87, 33, 2017, [2] Leistner et al., Phys.Rev. B 87, 224411, 2013, [3] Bauer et al., Nat. Mater. 14, 174, 2015, [4] Duschek et al., APL Mater. 4, 032301, 2016

MA 25.2 Wed 9:45 EB 202

Magnetoelectric memory function with optical readout — Vilmos Kocsis[1,2], Karlo Penc[2,3], Toomas Rõõm[4], Urmas Nagel[4], •Jakub Vít[2,5], Judit Romhányi[6], Yusuke Tokunaga[1], Yasujiro Taguchi[1], Yoshinori Tokura[1], István Kézsmárki[2,7], and Sándor Bordács[2] — [1]RIKEN CEMS, Japan — [2]Budapest University of Technology and Economics, Hungary — [3]HAS, Hungary — [4]NICPB, Estonia — [5]Institute of Physics ASCR, Czech Republic — [6]OISTGU, Japan — [7]EP5, University of Augsburg, Germany

The ultimate goal of multiferroic research is the development of new generation non-volatile memory devices, the so-called magnetoelectric (ME) memories, where magnetic bits are controlled via electric fields without the application of electrical currents, being subject to dissipation. This low-power operation exploits the entanglement of the magnetization and the electric polarization coexisting in multiferroic materials. Here I will demonstrate the optical readout of ME memory states in the antiferromagnetic (AFM) and antiferroelectric (AFE) $LiCoPO_4$, based on the strong absorption difference of THz radiation between its two types of ME domains. [1] This unusual contrast is attributed to the dynamic ME effect of the spin-wave excitations, as confirmed by our microscopic model, which also captures the characteristics of the observed static ME effect. Our proof-of-principle study, demonstrating the control and the optical readout of ME domains in $LiCoPO_4$, lays down the foundation for future ME memory devices based on antiferroelectric-antiferromagnetic insulators.

[1] V. Kocsis *et al.*, arXiv:1711.08124 (2017)

MA 25.3 Wed 10:00 EB 202

On-off switching of magnetism in ultrathin films of $La_{1-x}Sr_xMnO_3$ gated with an ionic liquid — •Alan Molinari, Robert Kruk, and Horst Hahn — Institute of Nanotechnology (INT), Karlsruhe Institute of Technology (KIT), Hermann-von-Helmholtz-Platz 1, 76344, Eggenstein-Leopoldshafen, Germany

Utilization of electric fields instead of conventional dissipative flowing currents to control magnetism may be the key for the realization of a variety of novel low-power microelectronic devices. In our work we addressed the control of the magnetization of ultrathin (about 3 nm) films of $La_{1-x}Sr_xMnO_3$ (LSMO) by means of ionic liquid (IL) gating. The magnetoelectric (ME) coupling[1,2] at the LSMO/IL interface was investigated under various conditions of temperature and applied voltage via in situ synchronized Superconducting Quantum Interference Device magnetometry and Cyclic Voltammetry. Thanks to the high surface-to-volume ratio of the films and the large amounts of surface charge densities attainable with the IL, ferromagnetism could be reversibly suppressed and restored in LSMO by application of just a few volts. Our results intend to bring to attention some appealing

functionalities of solid/liquid ME devices.
[1]A. Molinari et al., Nat. Comm. 8, 15339 (2017), doi:10.1038/ncomms15339
[2]A. Molinari et al., Adv. Mater. 1703908 (2017), doi: 10.1002/adma.201703908

MA 25.4 Wed 10:15 EB 202

Domain wall engineering as a route towards room temperature multiferroicity — •Konstantin Z. Rushchanskii, Stefan Blügel, and Marjana Ležaić — Peter Grünberg Institut, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Multiferroics are materials that exhibit two or more ferroic order parameters in a single phase. Their room-temperature functionality as well as the strong coupling of magnetic and electric order parameters are desired for devices of future electronics, such as multistate nonvolatile memory cells, electrically controlled spintronic devices, etc. Isostructural $Ga_{0.6}Fe_{1.4}O_3$ (GFO) [1] and ϵ-Fe_2O_3 (eFO) [2] are of special interest, due to simultaneous presence of ferrimagnetic coupling and a polar structure. Recently reported observation of room-temperature mutiferroic behavior in thin films of these compounds made them prospective materials for practical applications. Unfortunately, ferroelectric properties were experimentally observed only for a limited number of samples, and the conditions to have switchable polarization are still unclear.

We employ Density Functional Theory in combination with an evolutionary algorithm [3] to obtain realistic models of polarization switching in eFO and GFO. We will discuss the conditions, under which the films with maximal, switchable remanent ferroelectric polarization are obtained.

We acknowledge the support by 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

15 minutes break

MA 25.5 Wed 10:45 EB 202

Frustrated magnetism and magnetoelectric switching in RMn2O5 compounds — •Sergey Artyukhin and Louis Ponet — Italian Institute of Technology, Via Morego 30, Genova, Italy

Rare earth manganites RMn2O5 exibit complex magnetism and magnetically induced polarization, with chains of antiferromagnetically coupled Mn ions along a direction geometrically frustrated interchain interactions along b, and the competition of nearest and next-nearest neighbor exchanges along c leading to spiral states in YMn2O5. Here we use Landau theory and model Hamiltonian calculations with parameters obtained from density functional perturbation theory calculations to study magnetoelectric coupling and magnetic switching in these compounds.

MA 25.6 Wed 11:00 EB 202

A theoretical study on the electronic and magnetic excitation spectra of $BiFeO_3$ by dynamical mean-field theory — •Souvik Paul[1,2], Diana Iusan[1], Patrik Thunström[1], Yaroslav Kvashnin[1], Johan Hellsvik[1,3], Manuel Pereiro[1], Anna Delin[1,3], Biplab Sanyal[1], and Olle Eriksson[1] — [1]Department of Physics and Astronomy, Uppsala University, Sweden — [2]Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, Germany — [3]Department of Materials and Nano Physics, KTH Royal Institute of Technology, Sweden

Using local density approximation plus dynamical mean-field theory (LDA+DMFT), we have computed the electronic and magnetic excitation spectra of one of the popular multiferroic $BiFeO_3$. Our calculated eletronic spectra match very well with the experimental (hard X-ray photoelectron spectroscopy and resonant photoelectron spectroscopy for the Fe $3d$ states) spectra as compared to the commonly used LDA+U method, which fails drastically to produce the general features of the experimental spectra. This indicates the importance of correctly including the dynamical correlation among the Fe $3d$ orbitals to reproduce the experimental spectroscopic data. The LDA+DMFT derived density of states (DOS) exhibit significant amount of Fe $3d$ states at the position of Bi lone-pairs, implying that the latter are not alone in the spectral scenario. This fact might modify our interpretation about the origin of ferroelectric polarization in this material. Our magnetic excitation spectra computed from the LDA+DMFT results conform well with the inelastic neutron scattering data.

MA 25.7 Wed 11:15 EB 202

Magnetic field control of cycloidal domains and electric polarization in multiferroic $BiFeO_3$ — •Sándor Bordács[1], Dániel Farkas[1], Jonathan White[2], Robert Cubitt[3], Lisa DeBeer-Schmitt[4], Toshimitsu Ito[5], and István Kézsmárki[1,6] — [1]Department of Physics, Budapest University of Technology and Economics and MTA-BME Lendület Magneto-optical Spectroscopy Research Group, Budapest, Hungary — [2]Laboratory for Neutron Scattering and Imaging, PSI, Villigen, Switzerland — [3]Institut Laue-Langevin, Grenoble, France — [4]Oak Ridge National Laboratory, Oak Ridge, Tennessee, USA — [5]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Ibaraki, Japan — [6]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, Augsburg, Germany

The magnetic field induced rearrangement of the cycloidal spin structure in ferroelectric monodomain single crystals of the room-temperature multiferroic $BiFeO_3$ is studied using small-angle neutron scattering (SANS). The cycloid propagation vectors are observed to rotate when magnetic fields applied perpendicular to the rhombohedral (polar) axis exceed a pinning threshold value of $\sim$5 T. In light of these experimental results, a phenomenological model is proposed that captures the rearrangement of the cycloidal domains, and we revisit the microscopic origin of the magnetoelectric effect. A new coupling between the magnetic anisotropy and the polarization is proposed that explains the recently discovered magnetoelectric polarization to the rhombohedral axis.

MA 25.8 Wed 11:30 EB 202

Reversible Modulation of Magnetic Anisotropy in $Pb(Zr_{0.2}Ti_{0.8})O_3$ /$La_{0.8}Sr_{0.2}MnO_3$ Multiferroic Heterostructures — •Anil Rajapitamahuni, Lingling Tao, Evgeny Tsymbal, and Xia Hong — Department of Physics and Astronomy,University of Nebraska-Lincoln, Lincoln,NE, 68588

We report a reversible modulation of in-plane magnetic anisotropy energy (MAE) in 4 nm $La_{0.8}Sr_{0.2}MnO_3$ (LSMO) thin films via ferroelectric field effect induced charge doping facilitated by $Pb(Zr_{0.2}Ti_{0.8})O_3$(PZT) top gate. We employed, planar Hall effect measurements (PHE) to characterize the in-plane magnetic anisotropy in PZT/LSMO heterostructures. The magnetic anisotropy in LSMO is found to be biaxial with easy axes along <110> directions for both polarization states. The extracted biaxial anisotropy fields (H1) from PHE measurements, showed an enhancement in H1 in the accumulation state. Assuming a doping level change of 0.1 electron/Mn due to the polarization switching, the estimated anisotropy energy densities are 0.9 x 10^5 erg/cm^3 and 1.17 x 10^5 erg/cm^3 in the depletion and accumulation states respectively. This corresponds to a 30% enhancement of the MAE in the accumulation state when compared to the depletion state values. First principles density functional theory calculations performed for various Sr doping levels also show an increase in the MAE with an increase in the hole doping, agreeing well with our experimental observations. We attribute this enhancement in MAE to the modification of orbital contribution to spin-orbit coupling via ferroelectric field effect in LSMO.

MA 25.9 Wed 11:45 EB 202

Magnetoelectric effect in elastic multiferroic composites — •Yuliya Alekhina[1], Liudmila Makarova[1], Tatiana Rusakova[1], Olga Malyshkina[2], and Nikolai Perov[1] — [1]Lomonosov Moscow State University, Moscow, 11999, Russia — [2]Tver State University, Tver, 170100, Russia

Magnetorheological elastomers (MREs) are a type of "smart materials" changing their properties under the influence of external factors. MREs represent magnetic particles distributed in elastic medium. Under the magnetic field magnetic moments of particles tend to align what can lead to their shifting and rotating. Such ordering leads to several effects which can be observed in MREs, e.g. magnetorheological effect. It was previously shown that in MREs with both iron and graphite particles change of electrical resistance can be induced by magnetic field. In this case shifting of magnetic particles under the magnetic field creates the internal stresses in polymer matrix, which lead to displacements of the conductive graphite particles. Similar effect can be observed if ferroelectric particles are added to the MRE [1]. Those internal stresses can affect the movement of ferroelectric particles forcing to or preventing them from shifting and rotation thus changing the polarization process. The reverse effect is also possible: under the electric field, the magnetization process can be changed. Thereby, a type of multiferroic composite with elastically coupled ferromagnetic iron particles and ferroelectic PZT particles was prepared and investigated in this work. The work was financially supported by Grant RFBR 18-32-00354. [1] L.A. Makarova et al., IEEE Transactions on Magnetics, 2017, 53, 11, pp.7

MA 26: Thin films – coupling effects

Time: Wednesday 9:30–12:15 Location: EB 301

MA 26.1 Wed 9:30 EB 301

Influence of oxygen content on magnetic properties in La2/3Sr1/3MnO3-δ thin films — •Lei Cao[1], Oleg Petracic[1], Alexander Weber[1,2], Paul Zakalek[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 display a multitude of unique phenomena, such as various forms of magnetism, superconductivity, colossal magnetoresistance, and couplings between these states. The role of oxygen content after sample preparation onto the physical properties is mostly unknown. The ability to control the oxygen composition after the preparation may provide the possibility to dynamically tune the physical properties and establish a comprehensive understanding of the structure-property relationship. We report on the fabrication of La0.7Sr0.3MnO3-δ thin films on SrTiO3 substrates by high oxygen pressure sputtering. Using an in-situ x-ray diffraction setup we investigate the crystallographic properties while annealing the samples in vacuum and at various temperatures. While annealing induces a desorption of oxygen, absorption of oxygen is realized in a controlled oxygen plasma of a sputtering setup. By employing magnetometry and electrical resistivity measurements, we study the magnetic and transport properties of the as-prepared, annealed and plasma treated systems. We then relate the influence of oxygen absorption/desorption to the physical properties of the films.

MA 26.2 Wed 9:45 EB 301

Influence of deposition and field cooling parameters on sputter-deposited polycrystalline exchange bias layer systems — •Maximilian Merkel[1], Jonas Zehner[2], Karin Leistner[2], Dennis Holzinger[1], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel — [2]Leibniz Institute for Solid State and Materials Research Dresden, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden

Magnetic properties of sputter-deposited polycrystalline exchange bias thin films evolve from a complex interplay of different individual magnetic anisotropies which are directly connected to the grain size distribution, crystallite texture and interface structure of the layer system. These structural characteristics can be controlled via deposition parameters or manipulated during a thermal activation procedure in an external magnetic field. Angle-resolved hysteresis measurements using Kerr magnetometry in comparison to an extended Stoner-Wolfarth model [1], X-ray diffraction experiments and interface roughness characterization allowed for the quantification of material properties in dependence of deposition and field cooling parameters supporting common structure zone models.

[1] Müglich, N. D., Gaul, A., Meyl M., Ehresmann, A. , Götz, G., Reiss, G., Kuschel T., Time-dependent rotatable magnetic anisotropy in polycrystalline exchange-bias systems: Dependence on grain-size distribution, Physical Review B **94**, 184407 (2016)

MA 26.3 Wed 10:00 EB 301

Cooling field and sample orientation dependent magnetization reversal processes in exchange biased Co/CoO on MgO(100) — •Andrea Ehrmann[1] and Tomasz Blachowicz[2] — [1]Bielefeld University of Applied Sciences, Faculty of Engineering and Mathematics, 33619 Bielefeld, Germany — [2]Silesian University of Technology, Institute of Physics - Center for Science and Education, 44-100 Gliwice, Poland

Co/CoO is a typical exchange bias (EB) system which was investigated for long time, either as core/shell particles, as thin film systems or in other shapes. While other systems seem to be of higher interest in basic and applied research, a surprising effect could be found in Co/CoO thin film systems epitaxially grown on MgO(100) substrates: Such samples show a strong influence of the orientation of the average uncompensated antiferromagnetic magnetization with respect to the cooling field direction, resulting in unexpected asymmetric behavior during sample rotations. The horizontal loop shift as well as the sign of the transverse magnetization peaks in magneto-optical Kerr effect (MOKE) experiments change their values depending on the rotational direction. Here we will give a broad overview of the impact of cooling field and sample orientation on the magnetization reversal processes in this system.

[1] A. Ehrmann, T. Blachowicz: Angle and rotational direction dependent horizontal loop shift in epitaxial Co/CoO bilayers on MgO(100), AIP Advances 7, 115223 (2017)

MA 26.4 Wed 10:15 EB 301

Enhanced exchange bias in MnN/CoFe bilayers after high-temperature annealing — •Mareike Dunz, Jan Schmalhorst, and Markus Meinert — Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Germany

The exchange bias effect is crucial for pinning ferromagnetic electrodes in GMR or TMR devices. Recently, we found that optimized polycrystalline MnN/CoFe bilayer systems with $t_{\mathrm{MnN}} = 30\,\mathrm{nm}$ show exchange bias of up to 1800 Oe at room temperature [1]. This makes antiferromagnetic $\Theta-$MnN a promising alternative for expensive materials like MnIr.

Here, we report on even higher exchange bias that is observed in similar bilayers after annealing them at high temperatures around 500°C. For systems with $t_{\mathrm{MnN}} = 48\,\mathrm{nm}$, exchange bias of more than 2700 Oe is achieved. However, this is only observable for bilayers with thicknesses of MnN higher than 40 nm. To identify the origin of this behavior, X-ray diffraction and Auger depth profiling measurements were performed. They reveal a strong diffusion of nitrogen from the MnN into the Ta buffer layer of the samples. As thicker MnN layers have a better thermal stability due to their large nitrogen reservoir, they can tolerate the high annealing temperatures that induce the increase of exchange bias. Reversed field cooling experiments show that high-temperature annealing also yields an increased median blocking temperature of the MnN/CoFe system.

[1] M. Meinert et al., Phys. Rev. B 92(14), 144408 (2015)

MA 26.5 Wed 10:30 EB 301

Manipulation of Perpendicular AF-Coupled Thin Film Systems by Ion Beam Irradiation — •Leopold Koch[1,2], Miriam Lenz[1], Fabian Samad[2], Phani Arekapudi[2], Lorenzo Fallarino[1], and Olav Hellwig[1,2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstrasse 400, 01328 Dresden, Germany — [2]Institute of Physics, Chemnitz University of Technology, 09126 Chemnitz, Germany

The tuning of the magnetic properties of antiferromagnetically (AF) coupled multilayer films by ion beam irradiation has been investigated. Stacks of Co/Pt multilayers, AF-coupled by Ru interlayers, have been a model system for studying the energy contributions of interlayer exchange, perpendicular anisotropy and demagnetization [1]. The system shows a complex mixture of magnetic phases that can be tuned by the number of repeats of the Co/Pt-bilayers (X) and the number of Ru interlayers. A lateral homogeneous AF remanent magnetic structure occurs for small X due to the dominance of the AF-coupling. For large X the demagnetization energy prevails and ferromagnetic stripe domains evolve. Ion beam irradiation causes atomic intermixing at the Co/Pt and Co/Ru interfaces and successively changes the balance of the energy contributions. By irradiating locally, lateral heterogeneous structures of magnetic phases can be realized. Initial irradiation studies will be presented and discussed.

[1] O. Hellwig, J. B. Kortright, A. Berger and E. E. Fullerton, *J. Magn. Magn. Mater.*, 2007, 319, 13.

MA 26.6 Wed 10:45 EB 301

Interfacial Magnetic Exchange Coupling in a L10-MnGa/FeCo Bilayer — •Elvis Shoko and Udo Schwingenschloegl — King Abdullah University of Science and Technology, Physical Science and Engineering Division (PSE), Thuwal 23955-6900, Saudi Arabia

Epitaxial bilayers of L10-MnGa/Fe1-xCox are of interest in perpendicular magnetic tunnel junctions, with interfacial magnetic exchange coupling playing an important role in the functionality of such devices.[1] This exchange coupling is reported to undergo an abrupt transition from ferromagnetic (FM) to antiferromagnetic (AF) as x increases to 0.25. [2] The origin of this abrupt transition is not well understood. Using LDA+U density functional theory, we have studied the magnetic properties of these bilayers for compositions in the vicinity of x = 0.25. I will discuss the features of the exchange coupling that we obtain and some insight they provide in relation to the experimental result of Ref. 2.

[1] K. Z. Suzuki et al., Sci. Rep. 6, 30249 (2016). [2] Q. L. Ma et al., Phys. Rev. Lett. 112, 157202 (2014).

15 minutes break

MA 26.7 Wed 11:15 EB 301

TbCoFe/[Co/Ni/Pt] Exchange Coupled Heterostructure — •Michael Heigl, Ralph Wendler, Birgit Hebler, and Manfred Albrecht — Lehrstuhl für Experimentalphysik IV, Institut für Physik, Universität Augsburg, Germany

Heat-assisted magnetic recording (HAMR) is envisioned to increase the achievable storage density in future magnetic hard disk drives (HDD). We present a candidate composite structure consisting of two exchange-coupled materials with different Curie temperatures. The heterostructure consists of an amorphous ferrimagnetic TbCoFe thin film as a storage layer coupled to a softer [Co/Ni/Pt] multilayer, acting as a write and read-out layer. TbCoFe is in comparison to classic HAMR materials like $L1_0$FePt [1] highly tunable by its composition, exhibits a smaller Curie temperature T_c, larger damping, and perpendicular magnetic anisotropy (PMA). Due to its small magnetization, the switching and read-out layer [Co/Ni/Pt] is required. [Co/Ni/Pt] multilayers were chosen because of their PMA, high T_c and large saturation magnetization.

We report on the magnetic properties of the separate layers as well as the coupled system for different compositions, thicknesses, and temperatures. Additionally, the structural stability of the amorphous TbCoFe films and the multilayers were investigated as function of annealing temperature.

References: [1] D. Weller et al., Phys. Status Solidi A210 (2013) 1245.

MA 26.8 Wed 11:30 EB 301

Preparation and Characterization of Granular Magnetic Exchange Coupled Nano-Composites — •Runbang Shao[1], Benjamin Riedmüller[1], Balati Kuerbanjiang[1], Ulrich Herr[1], Adrian Schillik[2], and Berndt Koslowski[2] — [1]Institut für Mikro- und Nanomaterialien, Universität Ulm, Ulm, Deutschland — [2]Institut für Festkörperphysik, Universität Ulm, Ulm, Deutschland

Granular magnetic exchange coupled nano-composites have potentials in further increasing the storage density of hard disk drives, and producing permanent magnets with high energy product $(BH)_{max}$. These nano-composites of nano-particles (NPs) embedded in or covered by thin films were produced, using a combination of inert gas condensation (IGC) and sputter deposition, in which variable material combinations could be selected. The sizes and volume filling factor (VFF) of the NPs could be controlled independently. SEM, especially in transmission mode (T-SEM) was used to measure the NP sizes. In case of superparamagnetic NPs, we compared these results to the magnetic particle sizes obtained by fitting the m-H curve to a superposition of Langevin functions. For blocked NPs embedded in antiferromagnetic films, a dependence of exchange bias (H_{ex}) and coercivity (H_c) on the ferromagnetic NP VFF was observed. We also studied the magnetisation of individual NPs by the means of MFM.

MA 26.9 Wed 11:45 EB 301

Transport in graphene and possible Cooper pair formation — •Klaus Morawetz — Münster University of Applied Sciences,Stegerwaldstrasse 39, 48565 Steinfurt, Germany — International Institute of Physics- UFRN,Campus Universitário Lagoa nova,59078-970 Natal, Brazil — Max-Planck-Institute for the Physics of Complex Systems, 01187 Dresden, Germany

Based on the quantum kinetic equations for systems with SU(2) structure, regularization-free density and pseudospin currents are calculated in graphene realized as the infinite mass-limit of electrons with quadratic dispersion and a proper spin-orbit coupling. The currents possess no quasiparticle part but only anomalous parts. The intraband and interband conductivities are discussed with respect to magnetic fields and magnetic domain puddles. For large Zeeman fields the dynamical conductivities become independent of the density and are universal. The optical conductivity agrees well with the experimental values using screened impurity scattering and an effective Zeeman field. The universal value of Hall conductivity is shown to be modified due to the Zeeman field. The pseudospin current reveals an anomaly since a quasiparticle part appears though it vanishes for particle currents. The density and pseudospin response functions to an external electric field are calculated. A frequency and wave-vector range is identified where the dielectric function changes sign and the repulsive Coulomb potential becomes effectively attractive allowing Cooper pairing. Phys. Rev. B 94 (2016) 165415, Phys. Rev. B 92 (2015) 245425 errata: Phys. Rev. B93 (2016) 239904(E), Phys. Rev. B 92 (2015) 245426

MA 26.10 Wed 12:00 EB 301

Resonant states in graphene: Interplay with magnetic field and spin orbit coupling — •Jeongsu Lee, Denis Kochan, and Jaroslav Fabian — Institute for Theoretical Physics, University of Regensburg, 93040 Regensburg, Germany

A vacancy or an adatom in graphene induces π-magnetism and resonant scattering. Even without the magnetism in consideration, the resonant phenomenon can exhibit interesting physics when combined with an external magnetic field. A strong magnetic field in graphene induces Landau levels overlapping with the resonance peak near the Dirac point. As a result, the resonant state splits into two bound states with effective magnetic momenta of opposite sign. Employing realistic tight-binding parameters, we theoretically investigate the interplay between resonance scattering and the magnetic field in the presence of the magnetic moment and local spin-orbit coupling. This work is supported by SFB 1277.

MA 27: Spin currents and spin torques

Time: Wednesday 9:30–12:45 Location: EB 407

MA 27.1 Wed 9:30 EB 407

Spin pumping in ferrimagnets: Bridging ferro- and antiferromagnets — •Akashdeep Kamra and Wolfgang Belzig — Department of Physics, University of Konstanz, Germany

A combination of novel technological and fundamental physics prospects has sparked a huge interest in pure spin transport in magnets, starting with ferromagnets and spreading to antiferro- and ferrimagnets. We present a theoretical study of spin transport across a ferrimagnet/non-magnetic conductor interface, when a magnetic eigenmode is driven into a coherent state. Our model continuously encompasses systems from ferromagnets to antiferromagnets, thereby allowing analytical results for the full range of materials within a unified description. It further allows arbitrary (disordered and asymmetric) interfaces. The obtained spin current expression includes intra- as well as cross-sublattice terms. We find that the cross-sublattice terms, disregarded in previous studies, play an important role and result in qualitative changes to our understanding of spin pumping in antiferromagnets. The dc current is found to be sensitive to the asymmetry in interfacial coupling between the two sublattice magnetizations and the mobile electrons, especially for antiferromagnets.

References:

[1] A. Kamra and W. Belzig, Spin pumping and shot noise in ferrimagnets: bridging ferro- and antiferromagnets, Phys. Rev. Lett. 119, 197201 (2017).

[2] A. Kamra, U. Agrawal, and W. Belzig, Noninteger-spin magnonic excitations in untextured magnets, Phys. Rev. B 96, 020411 (R) (2017).

MA 27.2 Wed 9:45 EB 407

Magnon spin valve effect in a multilayer insulator spintronics system — •Joel Cramer[1,2], Felix Fuhrmann[1], Ulrike Ritzmann[1,3], Eiji Saitoh[4], Ulrich Nowak[3], and Mathias Kläui[1,2] — [1]für Physik, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [3]Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany — [4]WPI Advanced Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan

Magnon-based spintronic applications are a promising alternative to charge-driven devices regarding information transport and processing [1]. We report on ferromagnetic resonance spin pumping measurements in a magnonic spin valve device consisting of magnetic yttrium iron garnet (YIG)/CoO/Co multilayers. By means of microwaves and external magnetic fields YIG is brought into ferromagnetic resonance, thus emitting a pure spin current through the sample stack. The spin current propagates through the antiferromagnetic CoO and is detected in the Co layer via the inverse spin Hall effect [2]. The CoO furthermore enhances the Co coercive field, such that switching between a parallel or antiparallel alignment of the YIG and Co magnetization at the YIG resonance field is enabled. For parallel and antiparallel alignment we observe a very different amplitude of the detected magnonic spin current signal, resulting in a spin valve effect amplitude of 120% [3]. [1] Chumak *et al.*, Nat. Phys. **11**, 453 (2015) [2] Miao *et al.*, Phys. Rev. Lett. **111**, 066602 (2013) [3] Cramer *et al.*, arxiv:1706.07592

MA 27.3 Wed 10:00 EB 407

Enhancement of the Spin Pumping Effect by Two-Magnon Confluence Process in YIG-Pt Bilayers. — •Timo B. Noack, Vitaliy I. Vasyuchka, Dymitro A. Bozhko, Burkard Hillebrands, and Alexander A. Serga — TU Kaiserslautern, Kaiserslautern, Deutschland

Magnon spin currents are seen as a promising alternative to electrical charge currents for the transport and processing of information. Besides magnon-based elements operating with analogous and digital data, the field of modern magnon spintronics crucially depends on the progress in developing of effective converters between the magnon subsystem and the electron-carried spin and charge currents. This task is especially challenging in a case of short-wavelength exchange magnons, which application is promising for the miniaturization of magnonic devices. In Platinum (Pt) covered magnetic insulators such as Yttrium Iron Garnet (YIG, $Y_3Fe_5O_{12}$) films, combined action of the inverse spin-Hall effect (iSHE) and the spin-pumping (SP) effect constitutes an important mechanism allowing for the detection of this kind of magnons: Here, we present our studies on the efficiency of spin pumping in in-plane magnetized Pt-covered YIG films of different thicknesses. In our time-resolved field-dependent measurements of the iSHE-voltage, it has been found that at the given pumping frequency of $f_p = 14.449$ GHz a clearly visible sharp voltage peak appears at a bias magnetic field of approximately 1 kOe. This peak can be related to the confluence of two parametrically excited magnons with frequencies $f_p/2$ and wavevectors k_p into one magnon (f_p, $2k_p$).

MA 27.4 Wed 10:15 EB 407

Collective spin transport in easy-plane systems — •Martin Evers, Pascal Bolz, and Ulrich Nowak — University of Konstanz, D-78457 Konstanz

Spin transport has many aspects. It can occure as a spin polarized current or a magnon flow, moving magnetic textures as domain walls, spin spirals or skyrmions. One specific kind of transport is a collective spin current in an easy-plane magnet, that is called a spin superfluid [1,2]. This transport is predicted to be long-ranged and should also have a protection against dissipation. Within this framework also dissipationless spin transport has been predicted [1,3].

In our work, we study this spin superfluid transport numerically in an atomistic spin model in order to get insight into the possible mechanisms to drive such a supercurrent, to investigate the dissipation and the characteristic length scale of the transport. The systems we study include ferro- and antiferromagnets, as well as spin spirals and different driving mechanisms, such as a time-dependent Dzyloshinskii-Moriya interaction (originating from an electric field in an multiferroic material) [3], an injected spin accumulation and temperature gradients.

[1] J. König et al., Phys. Rev. Lett. **87**, 187202 (2001)
[2] S. Takei et al., Phys. Rev. Lett. **112**, 227201 (2014)
[3] W. Chen et al., Phys. Rev. Lett. **114**, 157203 (2015)

MA 27.5 Wed 10:30 EB 407

Long-distance supercurrent transport in a magnon Bose-Einstein condensate — •Alexander J.E. Kreil, Dmytro A. Bozhko, Alexander A. Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Currently, supercurrents in a room-temperature magnon Bose-Einstein condensate (BEC) have been reported [1]. The condensate is created by parametric microwave pumping in a tangentially magnetized yttrium-iron-garnet (YIG) film. We study the condensate by means of time-resolved Brillouin light scattering spectroscopy (BLS). By heating the sample, a spatially variation of the saturation magnetization is induced, which leads to a change of the magnon frequencies across the heated film. Because the magnon condensate is coherent across the entire heated area, a spatial varying phase shift is imprinted into its wavefunction. The spatial phase gradient generates a magnon supercurrent flowing out of the probing point. The earlier evidence of these supercurrents was obtained by an observation of the different relaxation behaviors of the magnon BEC under different heating conditions. By heating the sample with an external heat source, we are able to perform spatially resolved measurements. In this work we are showing the one-dimensional supercurrent transport measured over a large distance whereby travelling magnon density wave packets could be observed.

[1] Bozhko *et al.* Nature Physics **12**, 1057 (2016)

MA 27.6 Wed 10:45 EB 407

Unidirectional angular momentum transport in obliquely magnetized magnetic films — •Dmytro A. Bozhko[1], Halyna Yu. Musiienko-Shmarova[1], Vasyl S. Tyberkevych[2], Andrei N. Slavin[2], Ihor I. Syvorotka[3], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Department of Physics, Oakland University, USA — [3]Department of Crystal Physics and Technology, SRC "Carat", Ukraine

Thermal spectra of dipole-exchange magnons in an obliquely magnetized yttrium iron garnet (YIG) film were measured in a wide range of wavenumbers using a newly developed wavevector- and angle-resolved Brillouin light scattering (BLS) spectrometer. The YIG film of 5.6 μm thickness was grown in the (111) crystallographic plane on a gadolinium-gallium-garnet substrate by liquid-phase epitaxy. The experimentally measured magnon spectra agree well with the results of a theoretical analysis where transverse (thickness) profiles of the magnon modes were calculated. Calculations show that in the case of an in-plane magnetized film the thickness profile of the lowest magnon mode is a *standing* wave demonstrating dipolar "pinning", that gradually increases with the increase of the magnon in-plane wavenumber. In contrast, in the case of an oblique (out-of-plane) magnetization the thickness profiles of the magnon modes turn out to be *quasi-traveling* waves that do not transfer energy, but create a unidirectional flow of spin angular momentum (or spin current) along the film thickness. The work is supported by the DFG within the SFB/TR 49.

MA 27.7 Wed 11:00 EB 407

From kinetic instability to Bose-Einstein condensation and magnon supercurrent — •Halyna Yu. Musiienko-Shmarova[1], Alexander J.E. Kreil[1], Dmytro A. Bozhko[1], Victor S. L'vov[2], Anna Pomyalov[2], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Department of Chemical Physics, Weizmann Institute of Science, Rehovot 76100, Israel

By means of electromagnetic parametric pumping an ensemble of magnons, quanta of spin waves, can be prepared as an overpopulated Bose gas of weakly interacting quasiparticles. The evolution of this gas via magnon-magnon scattering processes can lead to the formation of a Bose-Einstein condensate (BEC) at the bottom of spin-wave spectrum. We studied this phenomena experimentally (by Brillouin light scattering spectroscopy) and theoretically in an yttrium-iron-garnet film in a wide region of the external magnetic field. This allows us to compare features of the condensation process in the cases when one of two physical mechanisms of the magnon transfer from a pumped high-frequency area to the BEC state prevails: a step-by-step Kolmogorov-Zakharov cascade of weak wave turbulence process or a kinetic-instability channel, which directly transfers magnons from the pumping area to the BEC point. As a result, we demonstrate the formation of a coherent condensed magnon state even in the presence of the kinetic instability processes leading to a strongly unbalanced non-equilibrium population of the low-energy part of the magnon spectrum. Financial support from the ERC Advanced Grant "SuperMagnonics" is acknowledged.

15 minutes break

MA 27.8 Wed 11:30 EB 407

Unified relativistic theory of magnetization dynamics with spin-current tensors — •Ritwik Mondal, Marco Berritta, and Peter M. Oppeneer — Department of Physics and Astronomy, Uppsala University, SE-75120 Uppsala, Sweden

Spin currents play a crucial role in operative properties of spintronic devices. To study current-driven magnetization dynamics, spin-torque terms providing the action of spin-polarized currents have previously been added in a phenomenological way to the Landau-Lifshitz-Gilbert (LLG) equation describing the local spin dynamics, yet without derivation from fundamental principles[1,2]. Starting from the Dirac-Kohn-Sham theory[3] and incorporating nonlocal spin transport we rigorously derive various spin-torque terms that appear in current-driven magnetization dynamics. In particular we obtain an extended magnetization dynamics equation that precisely contains the nonrelativistic adiabatic and relativistic nonadiabatic spin-transfer torques of the form proposed by Berger as well as relativistic spin-orbit torques[4]. We derive in addition a previously unnoticed relativistic spin-torque term and show that the various obtained spin-torque terms do not appear in the same mathematical form in the Landau-Lifshitz and LLG equations of spin dynamics.

[1]D. C. Ralph and M. D. Stiles, J. Magn. Magn. Mater. **320**, 1190 (2008). [2]P. Gambardella and I. M. Miron, Phil. Trans. Roy. Soc. London A **369**, 3175 (2011). [3]R. Mondal, M. Berritta and P. M. Oppeneer, Phys. Rev. B **94**, 144419 (2016). [4] S. Zhang and Z. Li, Phys. Rev. Lett. **93**, 127204 (2004).

MA 27.9 Wed 11:45 EB 407

Persistent precessions in spin-torque systems far from equilibrium — •Tim Ludwig[1], Igor Burmistrov[1,2,3], Yuval Gefen[4], and Alexander Shnirman[1] — [1]Institut für Theorie der Kondensierten Materie, Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [2]L. D. Landau Institute for Theoretical Physics RAS, 119334 Moscow, Russia — [3]Institut für Nanotechnologie, Karlsruhe Institute of Technology, 76021 Karlsruhe, Germany — [4]Department of Condensed Matter Physics, Weizmann Institute of Science, 76100 Rehovot, Israel

We consider persistent precessions of an itinerant single domain nanomagnet driven by a thermally induced spin-transfer torque current. In [1] it was found that, far from equilibrium, stationary adjustments of the electronic distribution functions can render electrically driven persistent precessions unstable. In contrast, as we now show, stable persistent precessions can be maintained by thermal driving even far from equilibrium. Interestingly, to obtain consistent results for the stability, we have to include dynamic adjustments of the distribution function to the trajectory of the magnetization. On the technical level, we follow the approach of [1], i.e., we derive an effective action of the Ambegaokar-Eckern-Schön type for the magnetization. For the determination of the stability, we have to extend the calculations of [1] and include higher orders terms.

[1] T. Ludwig, I.S. Burmistrov, Y. Gefen, A. Shnirman Phys. Rev. B 95, 075425 (2017)

MA 27.10 Wed 12:00 EB 407

Ab-initio study on $L1_0$ FePt-based magnetic tunnel junctions for memory applications — •Mario Galante, Matthew O. A. Ellis, and Stefano Sanvito — School of Physics, Trinity College Dublin, Ireland

Magnetic random access memory (MRAM) is believed to be one of the most promising candidates for the future of scalable non-volatile memories. At the heart of these devices are magnetic tunnel junctions (MTJs), which store data on the relative orientation of two magnetic layers separated by an insulating barrier and can be operated via electric currents exploiting the tunnelling magneto-resistance (TMR) and the spin-transfer torque (STT) effects. Junctions with out-of-plane magnetisation minimise the demagnetising field contribution to the switching current but a large magneto-crystalline anisotropy is required to keep such geometries. Common CoFeB/MgO devices have been shown to have a suitable anisotropy due to interface effects [1] but materials with large bulk anisotropy, such as $L1_0$-FePt, are also possible candidates. In this work, we have applied the SMEAGOL method [2] for *ab-initio* quantum transport to Fe/MgO/Fe MTJs with a $L1_0$-FePt layer inserted at the MgO-free layer interface. We investigate the suitability of FePt-based MTJs for memory applications by calculating the atom-resolved spin torque and the TMR in comparison with a Fe/MgO/Fe junction. We also consider the presence of a thin Fe seed layer and discuss how this influences the decay of the STT in the free layer. [1] A. Hallal, et al, PRB 88, 184423 (2013) [2] A. R. Rocha et al, PRB 73, 085414 (2006)

MA 27.11 Wed 12:15 EB 407

The effect of atomically varying anisotropy and damping on spin-transfer torque switching — •Matthew Ellis, Maria Stamenova, Mario Galante, and Stefano Sanvito — School of Physics and CRANN, Trinity College, Dublin 2, Ireland

Magnetic tunnel junctions (MTJs) form the principle unit for an array of emerging spintronic devices. Of particular interest are magnetic random access memory (MRAM) devices, where binary data is stored on the relative orientation of the two ferromagnetic layers in the MTJ. Of paramount importance to the future of MRAM is developing MTJs with material properties that provide a high readability with a low write threshold. The write threshold is determined by the effective magnetic anisotropy and damping of the free ferromagnetic layer and the strength of the spin-transfer torque (STT).

In this work, a multi-scale methodology, combining ab-initio calculations of spin-transfer torque with magnetisation dynamics computed at the atomic level, is used to model the current-induced switching in an ultra-thin Fe layer. Atomic resolved properties of the magnetic anisotropy, damping and STT are employed to explore how variations of these on the atomic scale alter the switching threshold. Little non-collinearity is observed due to the high exchange coupling while the total effective anisotropy and average damping determines the switching threshold.

MA 27.12 Wed 12:30 EB 407

Facet-dependent Spin-Orbit Torques in Mn3X (X=Ir, Ge) Chiral Antiferromagnets — James M. Taylor[1], •Edouard Lesne[1], Anastasios Markou[2], Pranava K. Sivakumar[1], Fasil K. Dejene[1], Claudia Felser[2], and Stuart S. P. Parkin[1] — [1]Max Planck Institute of Microstructure Physics, Halle (Germany) — [2]Max

Planck Institute for Chemical Physics of Solids, Dresden (Germany)

An active field of research aims at controlling materials magnetic properties at the nano-scale without resorting to external magnetic fields, through magneto-electric coupling or spin currents. Antiferromagnets displaying sizeable spin Hall effect (SHE) will enable new generation of spintronic devices operating without net magnetization.

The present work is motivated by the recent theoretical predictions [1,2], and experimental confirmations [3,4] of Berry curvature driven (giant) anomalous Hall effect (AHE) in chiral antiferromagnets of the Mn3X (X=Ge,Sn,Ir) family.

Here we report on temperature-dependent spin-transfer torque ferromagnetic resonance experiments in epitaxial [001]- and [111]-oriented films of Mn3Ir, and Mn3Ge(0001), grown by magnetron sputtering. Building upon their respective temperature and thickness-dependent anomalous Hall conductivity, we tentatively assess the contribution of bulk- and interface-driven spin-orbit torques, and discuss their origin in terms of intrinsic and extrinsic contributions.

[1] H. Chen et al., Phys.Rev.Lett. 112, 017205 (2014). [2] J. Kübler & C. Felser, Europhys.Lett. 108, 67001 (2014). [3] S. Nakatsuji et al., Nature 527, 212 (2015). [4] A. Nayak et al., Sci.Adv. 2:e1501870 (2016).

MA 28: Multiferroic Oxide Thin Films and Heterostructures I (joint session KFM/TT/MA)

Organizers: César Magén - University of Zaragoza, Aragón (Spain); Kathrin Dörr - Martin-Luther-Universität Halle-Wittenberg - Halle

Multiferroic oxide thin films and magnetoelectrically coupled oxide heterostructures are among the most attractive topics in the field of Complex Oxides. Within this extensive family of compounds, which are characterized by an unprecedented wealth of physical phenomena upon subtle variations of the structure or chemistry, multiferroics stand out due to the exciting novel physics underlying the coexistence and coupling of multiple ferroic orders. This exotic behavior bestows inherent multifunctionality upon these systems (either single-phase or heterostructure multiferroics), providing strong potential for future nanoelectronic devices.

Time: Wednesday 9:30–12:45 Location: EMH 225

Invited Talk MA 28.1 Wed 9:30 EMH 225
Oxygen vacancy controlled functionalities at interfaces of multiferroic tunnel junctions. — •Jacobo Santamaria — GFMC. Universidad Complutense 28040 Madrid

Oxygen vacancies are the most common defect in oxide perovskite oxides. Important applications are associated to their controlled generation and transport in electrochemical energy (fuel cells and batteries) and memory (memristors) devices. At interfaces oxygen vacancies can accumulate under the action of external electric fields and, especially in nanostructures be the source of novel, yet unreported, functionalities. Here we demonstrate the dynamic control of the vacancy profile in the nanometer thick barrier of a ferroelectric tunnel junction. Oxygen vacancies generated at an electrochemically active electrode accumulate towards the asymmetric interfaces of a ferroelectric tunnel barrier under the action of an external electric field and their ensuing doping effect modify the stability of ferroelectric polarization. I will further show that oxygen vacancies in a ferroelectric tunnel barrier may stabilize unexpected domain structures which control the tunneling transport providing a major step forward towards the new concept *The Wall is the Device* , to exploit the electronic properties of domain walls for ferroelectric tunnel barriers with new functionalities.

MA 28.2 Wed 10:00 EMH 225
Structure and Magnetism of the Co/PZT/LSMO Interface — •Holger Meyerheim[1], Arthur Ernst[2], Katayoon Mohseni[1], Andrey Polyakov[1], Nathalie Jedrecy[3], Andy Quindeau[1], Victor Antonov[1], Manuel Valvidares[4], Hari Vasili[4], and Pierluigi Gargiani[4] — [1]MPI f. Mikrostrukturphysik, D-06120 Halle — [2]Inst. für Th. Physik, JKU, A-4040 Linz, Austria — [3]INSP, UPMC-Sorbonne Univ., 75005 Paris, France — [4]Alba, 08290 Cerdanyola del Vallés, Spain

Using surface x-ray diffraction, x-ray absorption fine structure and x-ray circular dichroism (XMCD) experiments we have studied the geometric and magnetic properties of the $Co/Pb(Ti_{0.8}Zr_{0.2})O_3$ interface. Co deposition in submonolayer amounts on the 2 unit cells thick $(Ti,Zr)O_2$ terminated Pb $(Ti_{0.8}Zr_{0.2})O_3$ (PZT) layer leads to the formation of a perovskite type structure with Co-O distances of approximately 2.0 Å (octahedral) and 2.8 Å (cubic) in addition to a metallic Co-Co correlation near 2.4 Å. Co-$L_{2,3}$-XMCD spectra also reveal different Co environments, especially two Co-O contributions (A) and (B) related to the octahedral coordination (m=2.69μ_B) and the cubic coordination (m=2.33 μ_B). The XMCD analysis also evidences an anti-FM oriented induced moment at the PZT top layer Ti site (m=-0.005μ_B) related to the negative tunneling electro resistance effect. This result supports the "hybridization model" suggested by D.Pantel et al., Nat. Mat. 11, 289 (2012).

Support by SFB 762 (TP A5) is acknowledged. We thank E. Fonda (Samba at Soleil) and the ALBA staff for help during the experiments.

MA 28.3 Wed 10:15 EMH 225
Interfacial mechanisms in magneto-electric bismuth iron garnet thin films — •Laura Bocher[1], Adrien Teurtrie[1,2], Elena Popova[2], Odile Stéphan[1], Alexandre Gloter[1], and Niels Keller[2] — [1]Laboratoire de Physique des Solides - UMR 8502 CNRS, Université Paris-Sud, Orsay, FR — [2]Groupe d'Etude de la Matière Condensée - UMR8635 CNRS, UVSQ, Université Paris-Saclay, FR

Bismuth iron garnet (BIG) is ferrimagnetic with a relatively high magnetization (1600 G at 300 K), a magnetic ordering temperature from 650 K, and a giant Faraday rotation [1]. More recently, we evidenced a strong magneto-electric coupling at 300 K and above in BIG thin films opening new perspectives for an electric control of the magnetization [2]. However BIG can solely be elaborated in thin film form using non-equilibrium growth techniques and no bulk reference exists for conventional investigations. Hence precise knowledge on the atomic and electronic structures of BIG thin films remains a key challenge to understand better their structure-property relationships.

Here we will shed light on BIG thin films using advanced electron spectro-microscopy techniques, i.e. Cs-STEM/EELS, to identify how its cubic structure can accommodate locally different lattice mismatches through a variety of relaxation mechanisms and verify down to the scale of the atomic columns any possible cation interdiffusion and/or electronic reconstruction at the film/substrate interface [3].

[1] M. Deb, et al. J. Phys. D 45 (2012) 455001. [2] E. Popova et al. APL 110 (2017) 142404. [3] E. Popova et al. JAP 121 (2017) 115304

MA 28.4 Wed 10:30 EMH 225
Nonlinear spin-lattice coupling in EuTiO3: novel two-dimensional magneto-optical device for light modulation — •Annette Bussmann-Holder[1], Krystian Rolder[2], and Jürgen Köhler[1] — [1]Max-Planck-Institute for Solid State Research, Heisenbergstr. 1, D-70569 Stuttgart, Germany — [2]2Institute of Physics, University of Silesia, ul. Uniwersytecka 4, 40-007 Katowice, Poland

EuTiO3 is antiferromagnetic at low temperature, namely below TN=5.7K. In the high temperature paramagnetic phase the strongly nonlinear coupling between the lattice and the nominally silent Eu 4f7 spins induces magnetic correlations which become apparent in muon spin rotation experiments and more recently in birefringence measurements in an external magnetic field. It is shown here, that high quality films of insulating EuTiO3 deposited on a thin SrTiO3 substrate are versatile tools for light modulation. The operating temperature is close to room temperature and admits multiple device engineering. By using small magnetic fields birefringence of the samples can be switched off and on. Similarly, rotation of the sample in the field can modify its birefringence Δn. In addition, Δn can be increased by a factor of 4 in very modest fields with simultaneously enhancing the operating temperature by almost 100K. The results can be understood in terms of paramagnon phonon interaction where spin activity is achieved via the local spin-phonon double-well potential.

MA 28.5 Wed 10:45 EMH 225

Complexity in the structural and magnetic properties of almost multiferroic EuTiO3 thin films — Zurab Guguchia[1], Zaher Salman[2], •Hugo Keller[3], Krystian Roleder[4], Jürgen Köhler[5], and Annette Bussmann-Holder[5] — [1]Department of Physics, Columbia University, New York, New York 10027, USA — [2]Laboratory for Muon Spin Spectroscopy, Paul Scherrer Institut, CH-5232 Villigen PSI, Switzerland — [3]Physik-Institut der Universität Zürich, Winterthurerstrasse 190, CH-8057 Zürich, Switzerland — [4]Institute of Physics, University of Silesia, ul. Uniwersytecka 4, PL-40-007 Katowice, Poland — [5]Max-Planck-Institut für Festkörperforschung, Heisenbergstrasse 1, D-70569 Stuttgart, Germany

In a number of recent publications hidden magnetic properties at high temperatures have been reported for EuTiO3 (ETO), which orders antiferromagnetically below TN=5.7K. In addition, structural phase transitions have been discovered which correlate with the magnetic responses and can be tuned by a magnetic field. In order to identify the magnetic properties of ETO at temperatures well above TN, low-energy muon-spin rotation (μSR) experiments have been performed on thin films of ETO which exhibit all properties observed in bulk materials and are thus well suited to conclude about the magnetic order of the bulk. The μSR data reveal anomalies at 282 and 200 K related to the structural phase transitions in accordance with birefringence results. In addition, a transition to some kind of magnetic order below 100 K was observed as previously indirectly deduced from conductivity and dielectric constant measurements.

MA 28.6 Wed 11:00 EMH 225

Surface reconstructions and related local properties of a $BiFeO_3$ thin film — •Pengxiang Xu[1] and Lei Jin[2] — [1]Institute for Theoretical Physics, ETH Zurich — [2]Peter Grünberg Institute (PGI-5), Forschungszentrum Juelich

Coupling between lattice and order parameters, such as polarization in ferroelectrics and/or polarity in polar structures, has a strong impact on surface relaxation and reconstruction. However, up to now, surface structures that involve the termination of both matrix polarization and polar atomic planes have received little attention, particularly on the atomic scale. Here, we study surface structures on a $BiFeO_3$ thin film using atomic-resolution scanning transmission electron microscopy and spectroscopy. Two types of surface structure are found, depending on the polarisation of the underlying ferroelectric domain. On domains that have an upward polarisation component, a layer with an Aurivillius-Bi_2O_2-like structural unit is observed. Dramatic changes in local properties are measured directly below the surface layer. On domains that have a downward polarisation component, no reconstructions are visible. Calculations based on ab initio density functional theory reproduce the results and are used to interpret the formation of the surface structures.

15 min. break

MA 28.7 Wed 11:30 EMH 225

Domain engineering in BFO films — •Yeseul Yun[1,2], Niranjan Ramakrishnegowda[1,2], David Knoche[1,2], Daesung Park[1,2], and Akash Bhatnagar[1,2] — [1]Zentrum für Innovationskompetenz SiLi-nano, Halle (Saale), Germany — [2]Martin Luther Universität Halle-Wittenberg, Halle (Saale, Germany)

Multiferroic materials have attracted great attention due to their unusual physical properties and potential in device applications. The lead-free bismuth ferrite ($BiFeO_3$) is one of the most promising candidates. The domain structure plays a crucial role in determining ferroelectric and magnetic properties. Domains and domain walls can be modulated by parameters such as epitaxial strain, film thickness, substrate termination and presence of conductive layers.

In this study, we investigate the role of plume-related characteristics in obtaining long range order of ferroelastic domains in $BiFeO_3$ films. BFO/LSMO hetero-structures were fabricated using PLD on STO (001) substrate with different O_2 partial pressures. Preferential nucleation and long range ordering of 71° domain walls was achieved by varying the plume density, indicating the importance of plasma plume dynamics for the evolution of domain structure in the films. The role of strain and electrostatic energies was also analyzed in conjunction. The thickness of BFO was varied to modulate the extent of strain, while the electrostatic conditions were tuned by the thickness of LSMO.

MA 28.8 Wed 11:45 EMH 225

Domain Engineering of the Bulk Photovoltaic Effect in Bismuth Ferrite — •David Knoche[1,2], Niranjan Ramakrishnegowda[1,2], Yeseul Yun[1,2], and Akash Bhatnagar[1,2] — [1]Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Germany — [2]Zentrum für Innovationskompetenz SiLi-nano, Halle (Saale), Germany

The photovoltaic (PV) effect in multiferroic bismuth ferrite (BFO) can be largely attributed to the bulk photovoltaic (BPV) mechanism. The mechanism is associated to the absence of inversion symmetry in these materials. The principle of the BPV effect, that results in an above-bandgap open circuit voltage (V_{oc}), differs from the well-known photovoltaic effect observed in semiconductors like silicon, and still demands in-depth analysis. In this regard, the contribution of ferroic aspects, such as orientation of domains, is crucial and can be potentially used as a tuning parameter.

Thin films of single crystalline $BiFeO_3$ were grown epitaxially via pulsed laser deposition. Planar electrodes with different in-between distances were deposited on top of the sample. The domain orientations within the measurement gap were manipulated by applying high electric fields across the electrodes. Gradual increment in the applied electric field was crucial in obtaining intermediate domain architectures, that were visualized with piezo force microscope (PFM). Photoelectrical response was measured in conjunction to evaluate the influence on Voc and short circuit current.

MA 28.9 Wed 12:00 EMH 225

Investigation of a-domain formation in Pb(Zr,Ti)O3 thin films — •Niranjan Ramakrishnegowda[1,2], Yeseul Yun[1,2], Daesung Park[1,2], and Akash Bhatnagar[1,2] — [1]Zentrum für Innovationskompetenz SiLi-nano, Halle (Saale), Germany — [2]Martin Luther Universität Halle-Wittenberg, Halle (Saale), Germany

Strain engineering of ferroelectric/ferroelastic domains is an active area of research nowadays, as it provides an exotic pathway to tune the resultant properties of ferroic materials. Since the domains can be also ferroelastic, the extent of strain, applied via the substrate-film lattice parameter mismatch, can be used to define the domain width, orientation and position. However, the persistence of the strain across the thickness of the film is largely affected by growth related process parameters.

In the case of $Pb(Zr,Ti)O_3$, one of the most widely investigated ferroelectric, recent studies involving asymmetric substrates allowed to fine tune the nucleation of a-domains, and the associated domain wall thickness. The proposed prerequisite condition of $a_{film} < a_{substrate} < c_{film}$ was satisfied. In this work we attempt to further analyze this condition by growing PZT films on symmetric $SrTiO_3$ substrates. The role of depolarization field was evaluated by the use of conductive oxide layers sandwiched between the film and the substrate. The usually neglected contribution of target density and purity will be also elaborated.

MA 28.10 Wed 12:15 EMH 225

Continuous control of morphotropic phases by strain doping — •Andreas Herklotz[1], Stefania Florina Rus[2], Er-Jia Guo[3], Kathrin Dörr[1], and Thomas Zac Ward[3] — [1]Martin-Luther-Universität Halle-Wittenberg, Halle, Germany — [2]National Institute for Research and Development in Electrochemistry and Condensed Matter, Timisoara, Romania — [3]Oak Ridge National Laboratory, Oak Ridge, USA

The realization of a strain-driven morphotropic phase boundary in epitaxial $BiFeO_3$ (BFO) films has broadened this definition to single-phase materials and opened up great potential for advanced applications. However, a greater success of morphotropic systems in thin film technologies would require a *ex situ* control of the thin film's composition or strain state that is practically impossible with standard epitaxy approaches. Here we demonstrate that *ex situ* strain doping via low-energy helium implantation induces a complete phase transition from epitaxial rhombohedral-like to supertetragonal BFO films. This control over morphotropic phases is highly tunable and fully reversible via a high temperature anneal. We argue that strain doping of morphotropic films creates a new phase space based on internal and external lattice stress that can be seen as an analogue to temperature-composition phase diagrams of classical morphotropic ferroelectric systems.

This effort was wholly supported by the US Department of Energy (DOE), Office of Basic Energy Sciences (BES), Materials Sciences and Engineering Division, with user projects supported at ORNLs Center for Nanophase Materials Research (CNMS).

MA 28.11 Wed 12:30 EMH 225

Mechanical reading of ferroelectric polarity — •Gustau Catalan[1], Kumara Cordero[2], and Neus Domingo[2] — [1]ICREA-Institucio Catalana de Recerca i Estudis Avançats, Barcelona, Catalunya — [2]ICN2-Institut Catala de Nanociencia i Nanotecnologia, Barcelona, Catalunya

Flexoelectricity is polarization induced by strain gradient. It is closely related to piezoelectricity (polarization induced by strain), a phenomenon for which it was originally viewed as potential substitute. More recently, however, it has become apparent that very exciting new functionalities can be achieved when we combine both flexoelectricity and piezoelectricity in ferroelectrics.

One such functionality, reported in 2012, was the seminal discovery that strain gradients induced by the tip of an atomic force microscope (AFM) could mechanically *write* ferroelectric domains without applying any voltage. Here, we would like to report the complementary effect: the combination of flexoelectricity and piezoelectricity allows *reading* the polar sign of ferroelectric domains from pure (voltage-free) mechanical response.

MA 29: Topological Insulators I (joint session TT/MA)

Time: Wednesday 11:45–13:00 Location: A 053

MA 29.1 Wed 11:45 A 053

Towards universal Hong-Ou-Mandel correlations in topological insulators — •Andreas Bereczuk, Juan Diego Urbina, Cosimo Gorini, and Klaus Richter — Institut für Theoretische Physik, Universität Regensburg, Germany

The quantum-classical transition of the transmission probability for two fermions propagating through a quantum point contact is a known manifestation of the celebrated Hong-Ou-Mandel (HOM) effect [1] in electron quantum optics [2]. As shown in [3], universal HOM correlations are expected by substituting the quantum point contact by a chaotic cavity in a mesoscopic regime [3], where universality appears due to universal correlations of the scattering matrix entries at different energies. Here we present an analytical and numerical study of these correlations and propose electron quantum optics with cavities as complex beam splitters and edge states as waveguides as a candidate to observe universal HOM correlations in topological insulators.

[1] C. K. Hong, Z. Y. Ou, L. Mandel, PRL **59**, 2044 (1987)
[2] E. Bocquillon et al., Annalen der Physik **526**, 1 (2014)
[3] J. D. Urbina et al., Phys. Rev. Lett. **116**, 100401 (2016)

MA 29.2 Wed 12:00 A 053

Effects of local approximations on topological phases — •Thomas Mertz, Karim Zantout, and Roser Valenti — ITP, Goethe University, Frankfurt am Main

We investigate the self-energy dispersion of topological models and its effect on the topological classification in terms of invariants computed in the framework of the so-called topological Hamiltonian, an auxiliary Fermi-liquid like theory. The concept of topology in physics has matured as a non-interacting theory, most of its properties deeply intertwined with the conventional band theory of solids. Recently, a lot of interest has shifted towards interacting systems, which have not been studied extensively from a topological point of view. Since the topological Hamiltonian is determined by the zero-frequency value of the self-energy only, which has been studied using local theories, we focus on the explicit momentum-dependence captured by methods such as TPSC and CPT.

MA 29.3 Wed 12:15 A 053

Spin-phonon scattering in edge states of two-dimensional topological insulators — •Solofo Groenendijk, Giacomo Dolcetto, and Thomas Schmidt — Physics and Materials Science Research Unit, University of Luxembourg, L-1511 Luxembourg

We study theoretically the effect of electron-phonon scattering in 2D topological insulator (2DTI) edge states. Due to the spin-momentum locking in helical edge states, dynamical deformations of the edge modify the spin texture of the electronic edge states. In our work, we show that the resulting spin-phonon coupling ultimately leads to backscattering.

For a short channel, we compute the temperature-dependent conductance in the linear regime ($\beta eV < k_B T$) using the Kubo formula, and find $\delta G \propto T^5$ for the backscattering conductance. In the limit of a long edge channel, transport becomes diffusive and we compute the resistivity ρ using the semi-classical Boltzmann equation. In particular we find a metallic Bloch-Grüneisen behaviour for chemical potentials near the Dirac point.

Since this spin-phonon coupling arises even in ideal samples and since further imperfections (e.g. Rashba impurities, charge puddles, electron-electron interactions etc.) can only increase backscattering, our results impose a fundamental upper limit on the conductivity of 2D TI edge states.

MA 29.4 Wed 12:30 A 053

Topological invariants for Floquet-Bloch systems with chiral, time-reversal, or particle-hole symmetry — •Bastian Höckendorf, Andreas Alvermann, and Holger Fehske — Institut für Physik, Ernst-Moritz-Arndt-Universität Greifswald, Greifswald, Germany

We introduce $\mathbb{Z}_2$-valued bulk invariants for symmetry-protected topological phases in $2+1$ dimensional driven quantum systems. These invariants adapt the W_3-invariant, expressed as a sum over degeneracy points of the propagator, to the respective symmetry class of the Floquet-Bloch Hamiltonian. The bulk-boundary correspondence that holds for each invariant relates a non-zero value of the bulk invariant to the existence of symmetry-protected topological boundary states. To demonstrate this correspondence we apply our invariants to a chiral Harper, time-reversal Kane-Mele, and particle-hole symmetric graphene model with periodic driving, where they successfully predict the appearance of boundary states that exist despite the trivial topological character of the Floquet bands. Especially for particle-hole symmetry, combination of the W_3 and the $\mathbb{Z}_2$-invariants allows us to distinguish between weak and strong topological phases.

[1] B. Höckendorf, A. Alvermann, and H. Fehske, J. Phys. A 50, 295301 (2017).
[2] B. Höckendorf, A. Alvermann, and H. Fehske, preprint, arXiv:1708.07420 (2017).

MA 29.5 Wed 12:45 A 053

Reduced many-body formulas for the macroscopic polarization and topological charge pumping — •Ryan Requist[1] and Eberhard K. U. Gross[1,2] — [1]Max Planck Institute of Microstructure Physics, Halle, Germany — [2]Fritz Haber Center for Molecular Dynamics, Jerusalem, Israel

In ab initio materials research, topological invariants and the macroscopic polarization are usually calculated in terms of an effective single-particle Kohn-Sham band structure, an approach which may give incorrect results even if the exact exchange-correlation potential is used. We propose a simple natural orbital geometric phase formula for the macroscopic polarization and verify that it accurately reproduces the polarization in the Rice-Mele-Hubbard model in strongly and weakly correlated regimes. An analogous formula based on a one-body reduced Berry curvature very accurately predicts the critical Hubbard interaction at which Thouless charge pumping is quenched. We discuss strategies for ab initio calculations of natural orbital geometric phases and the possibility of extending the approach to other topological invariants in correlated materials.

MA 30: Focus Session: Topological Defects in Superconductors and Magnets (joint session TT/MA)

Vortices in superconductors and skyrmions in magnets are two examples of topological objects that can form a lattice and have particle-like properties. Their orientation and symmetry is determined by the magnetic field and the interaction within the material. The scientific and methodological approaches are similar*both can be studied using transport and magnetization and both can be observed using neutron scattering and scanning microscopies. Nanofabrication, often with the help of hybrid structures, allows controlling and manipulating them. The latter is believed to play a key role in applications involving current carrying and magnetic memory devices. The aim of the colloquium is to present most recent advances with a particular focus on the cross-fertilization of research on topological defects in superconductivity and magnetism.

Organization: Sebastian Mühlbauer, TU München; Hermann Suderow, Universidad Autonoma de Madrid; Javier Villegas, Thales, Paris; Markus Garst, TU Dresden

Time: Wednesday 15:00–17:45 Location: H 0104

Invited Talk MA 30.1 Wed 15:00 H 0104
Stability and Emergent Electrodynamics of Skyrmions — •Christian Pfleiderer — Physik-Department, Technische Universität München, D-85748 Garching, Germany

Skyrmions and related topological spin textures in chiral magnets attract great interest as a possible route towards novel spintronics devices. A series of studies is reported on the topological stability of skyrmions in chiral magnets for different temperature versus field histories. The character of magnetic textures, notably as observed in bulk compounds, at surfaces and in thin epitaxial films will be addressed. Further, the response of the different magnetic phases in chiral magnets to electric currents and the associated spin currents across the magnetic phase diagram of selected systems has been measured. Based on the combination of electrical resistivity, Hall effect, planar Hall effect, ac susceptibility and kinetic small angle neutron scattering the interplay of spin transfer torques with defects for the different magnetic phases and phase boundaries will be discussed.

Invited Talk MA 30.2 Wed 15:30 H 0104
Optical Manipulation of Single Flux Quanta — •Philippe Tamarat — LP2N, Université de Bordeaux, Institut d'Optique Graduate School and CNRS, France

The semiconductor electronics scaling road map will probably reach its physical fundamental limits within the next decade. Alternative technologies such as superconducting electronics are appealing due to higher operating frequencies together with fundamentally lower switching energies. In this context, a promising method requires the manipulation of individual flux quanta close to a Josephson junction. Yet, handling of individual vortices remains challenging and has been performed only with local probe scanning microscopies, slow techniques that are heavy to implement in a cryogenic environment.

We introduce the concept of laser manipulation of individual flux quanta, based on local heating of the superconductor with a focused laser beam to realize a fast, precise and non-invasive manipulation of an Abrikosov vortex, in the same way as with optical tweezers. This simple and far-field optical method provides a perfect basis for sculpting the magnetic flux profile in superconducting devices like a vortex lens or a vortex cleaner. Various regimes of vortex manipulation are achieved, from the precise and rapid positioning of individual vortices to the generation of tight vortex bunches. This method will fuel fundamental investigations of the vortex matter and open up new research directions in quantum computation based on Josephson junctions. I will also present our latest advances towards the creation of Abrikosov vortices with light.

Invited Talk MA 30.3 Wed 16:00 H 0104
Skyrmion Lattices in Random and Ordered Potential Landscapes — •Charles Reichhardt — Los Alamos National Laboratory, Los Alamos, USA

Since the initial discovery of skyrmion lattices in chiral magnets [1], there has been a tremendous growth in this field as an increasing number of compounds are found to have extended regions of stable skyrmion lattices [2] even close to room temperature [3]. These systems have significant promise for applications due to their size scale and the low currents or drives needed to move the skyrmions [4]. We examine the driven dynamics of skyrmions interacting with random and periodic substrate potentials using both continuum based modelling and particle based simulations. In clean systems we examine the range in which skyrmion motion can be explored as a function of the magnetic field and current and show that there can be a current-induced creation or destruction of skyrmions. In systems with random pinning we find that there is a finite depinning threshold and that the Hall angle shows a strong dependence on the disorder strength. We also show that features in the transport curves correlate with different types of skyrmion flow regimes including a skyrmion glass depinning/skyrmion plastic flow region as well as a transition to a dynamically reordered skyrmioncrystal at higher drives. We find that increasing the Magnus term produces a low depinning threshold which is due to a combination of skyrmions forming complex orbits within the pinning sites and skyrmion-skyrmion scattering effects.

15 min. break.

Invited Talk MA 30.4 Wed 16:45 H 0104
Hedgehog Spin-Vortex Crystal Magnetic Order in Superconducting $CaK(Fe_{1-x}M_x)_4As_4$ (M=Co, Ni) — •Anna Böhmer — Ames Laboratory, Iowa, USA — IFP, Karlsruhe Institute of Technology, Germany

Iron-based superconductors can support a number of antiferromagnetic phases, of which stripe-type antiferromagnetism is most common. It is found that Ni- and Co-doping in $CaKFe_4As_4$ suppresses superconductivity and stabilizes a new antiferromagnetic phase. This phase is studied using thermodynamic, transport, x-ray and neutron diffraction, as well as local magnetic measurements. A non-collinear antiferromagnetic structure preserving tetragonal symmetry is revealed. It is characterized by a superposition of the propagation vectors of the common stripe-type antiferromagnetism. This antiferromagnetic structure with a "hedgehog-type" moment motif is stabilized by the reduced symmetry of the $CaKFe_4As_4$ structure.

This work was performed in collaboration with W. R. Meier, Q.-P. Ding, A. Kreyssig, M. Xu, S. L. Bud'ko, A. Sapkota, K. Kothapalli, J. M. Wilde, W. Tian, V. Borisov, R. Valentí, C. D. Batista, P. P. Orth, R. M. Fernandes, R. J. McQueeney, A. I. Goldman, Y. Furukawa and P. C. Canfield and supported by the Gordon and Betty Moore Foundation's EPiQS Initiative through Grant GBMF4411 and the US DOE, Basic Energy Sciences under Contract No. DE-AC02-07CH11358.
[1] W. R. Meier et al., arXiv:1706.01067 (2017).

Invited Talk MA 30.5 Wed 17:15 H 0104
Geometric Frustration and Ratchet Effect of Vortices in an Artificial-Spin/Superconductor Hybrid — •Zhi-Li Xiao[1,2], Yong-Lei Wang[1,3], Xiaoyu Ma[3], Jing Xu[1,2], Boldizsar Janko[3], and Wai-Kwong Kwok[1] — [1]Materials Science Division, Argonne National Laboratory, Argonne, Illinois 60439, USA — [2]Department of Physics, Northern Illinois University, DeKalb, Illinois 60115, USA — [3]Department of Physics, University of Notre Dame, Notre Dame, Indiana 46556, USA

Geometric frustration emerges when local interaction energies cannot be simultaneously minimized, resulting in numerous degenerate states. It exists in a large variety of material systems, such as water ice and pyrochlore crystals (spin ice), as well as various artificial systems including artificial spin ice, vortex ice, magnetic colloidal ice, and buckled colloidal monolayers. However, it is difficult to achieve extensive degeneracy, especially in a two-dimensional (2D) system. Here, we report the realization of geometric frustration with massive degeneracy in a 2D system created in a superconducting thin film placed underneath an artificial-spin structure. The magnetic charges of the artificial-spins strongly interact with vortices in the superconductor, enabling the creation of controllable frustrated and crystallized vortex states by precise selection of the spin magnetic states. We reveal the various vortex states by molecular dynamic simulations and transport measurements. We demonstrate that a reprogrammable vortex ratchet effect can be achieved in this artificial-spin/superconductor heterostructure.

MA 31: Magnonics I

Time: Wednesday 15:00–18:15 Location: H 0110

Topical Talk MA 31.1 Wed 15:00 H 0110

Magnonics, Quo Vadis? — •Volodymyr Kruglyak — University of Exeter, CEMPS, Exeter, United Kingdom

Starting from a brief general introduction to the topic of magnonics, I will present an overview of its state of the art and opportunities for future developments, in mind with questions: What spin wave applications could be realised with what we have? What challenges need to be resolved to enable further spin wave applications? Why is magnonics fun even if one is not bothered by applications? Among other themes, I will discuss and provide demonstrations of exciting new physics and technological opportunities associated with the graded magnonic index and spin wave Fano resonances, promoting them as the next big thing in magnonics research. The research leading to these results has received funding from the Engineering and Physical Sciences Research Council of the United Kingdom (Project Nos. EP/L019876/1, EP/L020696 EP/P505526/1 and EP/L015331/1) and from the European Union*s Horizon 2020 research and innovation program under Marie Skłodowska-Curie Grant Agreement No. 644348 (MagIC).

MA 31.2 Wed 15:30 H 0110

Direct observation of Sub-100 nm spin-wave propagation in magnonic waveguides — •Nick Träger[1], Paweł Gruszecki[2], Filip Lisiecki[3], Johannes Förster[1], Markus Weigand[1], Piotr Kuswik[2,3], Janusz Dubowik[3], Gisela Schütz[1], Maciej Krawczyk[2], and Joachim Gräfe[1] — [1]MPI for Intelligent Systems, Stuttgart — [2]Adam Mickiewicz University, Poznan — [3]Institute of Molecular Physics, Poznan

In magnonics research, capabilities of data processing mediated by spin-waves are of current interest and promise beyond-CMOS technologies, providing efficient guiding of information between logic elements. Here, we investigate 350, 700 and 1400 nm wide, and 50 nm thin Py stripes as spin-wave guides. Continuous wave RF fields were generated in a 2 μm wide antenna to excite spin waves into these Py stripes. Using magnetic scanning x-ray microscopy (MAXYMUS@BESSY) with 18 nm spatial and 35 ps temporal resolution, we directly observe highly oriented emission and propagation of sub-100 nm spin-wave modes in these wave guides. Furthermore, we tested that they are capable of simultaneously carrying multiple modes and explored the dispersion behaviour by burst experiments. Thus, a rich data transmission scenario was created, unveiling the interleaving mode behaviour during these information pulses. Non-dispersive propagation was observed for the wave guide length of 12 μm, indicating high transmission velocity with uniform characteristics that are promising for future technical applications.

MA 31.3 Wed 15:45 H 0110

Spin pinning conditions in nano-scale spin-wave waveguides — Qi Wang[1], Roman Verba[2], Martin Kewenig[1], Björn Heinz[1], Philipp Pirro[1], Thomas Meyer[1], Carsten Dubs[3], •Thomas Brächer[1], and Andrii Chumak[1] — [1]Fachbereich Physik, Technische Universitaet Kaiserslautern, Kaiserslautern, Germany — [2]Institute of Magnetism, Kyiv 03680, Ukraine — [3]INNOVENT e.V., Technologieentwicklung, Prüssingstraße 27B, 07745 Jena, Germany

The research field of magnonics deals with the transport of information via spin waves in ever decreasing spin-wave conduits. As the used spin-wave waveguides approach nanometric scales, the spin-wave mode profiles have to be revisited. In particular, if the lateral sizes of the waveguide approaches the exchange length, dipolar pinning is not dominant anymore. Studying the model system yttrium iron garnet (YIG), we demonstrate that this leads to an exchange-mediated unpinning in waveguides with widths on the order of 100 nm and we discuss the impact of this unpinning on the spin-wave spectra. This research has been supported by ERC Starting Grant 678309 MagnonCircuits and DFG Grant DU 1427/2-1.

MA 31.4 Wed 16:00 H 0110

Broadband Magnetoelastic and Magnetostatic Spin Wave Emission by Magnetic Domain Walls — •Rasmus Holländer, Cai Müller, and Jeffrey McCord — Institute for Materials Science, Kiel University, Kaiserstraße 2, 24143 Kiel, Germany

We investigate the linear dynamic magnetization response of an amorphous CoFeB stripe element in different domain states by homogeneous Oersted-field excitation. Coherent spin waves emitted by the domain walls can be directly observed by component-selective time-resolved magneto-optical wide-field imaging. The system is modeled in a two dimensional micromagnetic model. Magnetoelastic and magnetostatic spin waves can be distinguished by their dispersion and relation to magnetization orientation and domain wall orientation. The emission of spin waves from excited micromagnetic objects is a general physical phenomenon relevant for magnetization dynamics in patterned magnetic thin films.

The authors thank the German Science Foundation (DFG) for the financial support (grant Mc9/9-2 and Mc9/10-2).

MA 31.5 Wed 16:15 H 0110

Taking an electron-magnon duality shortcut from electron to magnon transport — •Alexander Mook[1], Börge Göbel[2], Jürgen Henk[1], and Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität, D-06120 Halle — [2]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle

The quasiparticles in insulating magnets are the charge-neutral magnons, whose magnetic moments couple to electromagnetic fields. For collinear easy-axis magnets, this coupling can be mapped elegantly onto the scenario of charged particles in electromagnetic fields. From this mapping we obtain the same equations of motion for magnon wave packets as for electron wave packets in metals. Thus, well-established electronic transport phenomena can be carried over to magnons: this 'duality shortcut' facilitates the discussion of magnon transport. We identify the magnon versions of normal and anomalous Hall, Nernst, Ettingshausen, and Righi-Leduc effects. They are discussed for selected types of easy-axis magnets: ferromagnets, antiferromagnets, and ferrimagnets. Besides a magnon Wiedemann-Franz law and the magnon counterpart of the negative magnetoresistance of electrons in Weyl semimetals, we predict that certain low-symmetry ferrimagnets exhibit a nonlinear version of the anomalous magnon Hall effect family.

MA 31.6 Wed 16:30 H 0110

Magnonic crystals with spatial modulation of magnetic anisotropy — •Lukáš Flajšman[1], Ondřej Wojewoda[2], Viola Křižáková[2], Jonas Gloss[3], Igor Turčan[1], Michael Schmid[3], Michal Urbánek[1,2], and Peter Varga[1,3] — [1]CEITEC BUT, Brno, Czech Republic — [2]IPE, BUT, Brno, Czech Republic — [3]TU Wien, Wien, Austria

Artificially patterned periodic magnetic structures - magnonic crystals - are prospective materials for controlling and manipulating spin waves. Most common types of magnonic crystals are based on periodic alternation of saturation magnetization or material thickness. We investigate the possibility of inducing the frequency band-gap by periodic modulation of direction of uniaxial anisotropy. In our approach in order to fabricate structures with periodic spatial modulation of uniaxial anisotropy we use a metastable paramagnetic fcc Fe thin films on Cu(100) substrate, which can be locally transformed by focused ion beam (FIB) to ferromagnetic bcc Fe phase [1]. The transformed areas have highly ordered crystallographic structure which can be to some extend controlled by proper selection of the FIB irradiation procedure. This permits the control of the magnetic anisotropy (type and direction) of the transformed areas. us to prepare magnonic crystals with modulation in direction of uniaxial anisotropy. We further investigate the band-structure of magnonic crystals with modulated uniaxial magnetic anisotropy by micromagnetic simulations.

[1] J. Gloss, S. Shah Zaman, J. Jonner, Z. Novotny, M. Schmid, P. Varga, M. Urbánek, Appl. Phys. Lett. 103 (2013) 262405

15 minutes break

MA 31.7 Wed 17:00 H 0110

Reprogrammable, zero-field spin-Hall nano-oscillators based on domain walls — Nana Nishida[1], Toni Hache[1,3], Sri Sai Phani Kanth Arekapudi[3], Olav Hellwig[1,3], and •Helmut Schultheiss[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung, Dresden, Germany — [2]TU Dresden, Germany — [3]TU Chemnitz, Germany

Spin-Hall nano-oscillators are nano-scale devices for the generation of magnons and rf-signals. They are based on pure spin currents generated by the spin-Hall effect in heavy metals and the subsequent spin-transfer-torque acting on the magnetization of an adjacent ferromagnetic layer. This transfer of angular momentum can compensate the intrinsic damping of the ferromagnetic layer which results in auto-oscillations of the magnetization. For a high efficiency of this transfer of angular momentum in bilayers of a heavy metal and a ferromagnet, the magnetization needs to be perpendicular to the direction of the injected dc current. Typically, this requires the application of large external magnetic fields. We present an approach based on magnetic domain walls in nano-wires which shows strongly confined auto-oscillations without the application of any magnetic field.

MA 31.8 Wed 17:15 H 0110

Spin-Wave Optics in Magnetization Landscapes — Rick Assmann[1], •Marc Vogel[1], Andrii V. Chumak[1], Burkard Hillebrands[1], and Georg von Freymann[1,2] — [1]Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Str. 56, 67663 Kaiserslautern — [2]Fraunhofer-Institute for Industrial Mathematics ITWM, Fraunhofer-Platz 1, 67663 Kaiserslautern

Spin-wave propagation in ferrimagnetic films (several micrometers thick yttrium iron garnet) follows the well-known laws of optical propagation, e. g., Snell's law of refraction [Phys. Rev. Lett. 117, 037204 (2016)]. In conventional optics, low divergent light beams are often used in the experimental setup. To do optics with spin waves, the excitation of spin-wave beams is necessary. Therefore, we use specially designed coplanar waveguides or microstrip antennas [Sci. Rep. 6, 22367 (2016)]. The spin-wave propagation can be observed in the experiment with micro-structured induction probes, which are scanned over the sample. We propose to use optically-induced magnetization landscapes [Nature Physics 11, 487 (2015)] to create the building blocks of spin-wave optics, e. g., spin-wave (graded-index) lenses, fibers, beam-splitter or diffraction gratings. Moreover, spin-wave Fourier optics can be realized by exploiting the properties of spin-wave lenses. We compare our experimental results with micromagnetic simulations.

Financial support by DFG collaborative research center SFB/TRR 173 "Spin+X" (project B04) is gratefully acknowledged.

MA 31.9 Wed 17:30 H 0110

Tailoring spin-wave eigenfrequencies in Py films with Co-Fe-FEBID nanodisks embedded into square antidot lattices — •Oleksandr V. Dobrovolskiy[1,2], Roland Sachser[1], Sergey A. Bunyaev[3], Gleb N. Kakazei[3], Felix Stobiecki[4], Janusz Dubowik[4], Piotr Kuswik[4], Maciej Krawczyk[5], Michael Huth[1], and Ruslan V. Vovk[2] — [1]Goethe University, Frankfurt am Main, Germany — [2]V. Karazin National University, Kharkiv, Ukraine — [3]IFIMUP-IN Universidade do Porto, Porto, Portugal — [4]IMP Polish Academy of Sciences, Poznań, Poland — [5]Adam Mickiewicz University in Poznań, Poznań, Poland

The spin-wave eigenfrequencies in 30 nm-thick Py films with Co-Fe nanodisks of different heights embedded in antidots were studied by VNA-FMR spectroscopy in the 10 K to 300 K temperature range and compared with a reference plain Py film. The antidots with 200 nm in diameter were milled by Ga focused ion beam and formed a square lattice with a period of 600 nm. The Co-Fe nanodisks were deposited inside of the antidots by focused electron beam induced deposition (FEBID). The external field H was applied along the edge of the unit cell of the bicomponent magnonic crystal thus formed. In the Py sample with antidots, in addition to the FMR mode of the plain film, modes resulting from the nanopatterning have been observed. In the Py/Co-Fe-FEBID sample, further modes depending on H and the antidot volume fraction filled with Co-Fe-FEBID have been revealed. The role of the Co-Fe-FEBID disks in the broadening of the FMR linewidth is discussed.

MA 31.10 Wed 17:45 H 0110

Bose-Einstein Condensation of Quasi-Particles in a Dynamically Cooled System — •Michael Schneider[1], Thomas Brächer[1], Viktor Lauer[1], Phillip Pirro[1], Alexander A. Serga[1], Bert Lägel[2], Carsten Dubs[2], Andrei Slavin[3], Vasyl S. Tiberkevich[3], Burkard Hillebrands[1], and Andrii V. Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]INNOVENT e.V., Technologieentwicklung, Jena, Germany — [3]Oakland University, Rochester, USA

Recently the formation of magnon Bose-Einstein Condensates (BEC) in extended films attracted large attention. In previous studies the conditions for the formation of the BEC are artificially created by parametric pumping. Here we present a fundamentally new approach. Fast DC current pulses applied to yttrium-iron-garnet (YIG)/Pt microstructures result in a strong heating. Consequently, this leads to an increased number of magnons, distributed over the whole spectrum. Once the current is switched off the micro-sized system cools down rapidly. This results in a strong increase of the magnon density at the bottom of the spectrum. That is observed using time-resolved Brillouin light scattering spectroscopy. Our experiment shows, that the BEC formation depends on the magnon temperature and the timescale of the cooling process. This research has been supported by ERC Starting Grant 678309 MagnonCircuits, ERC Advanced Grant 694709 SuperMagnonics and DFG Grant DU 1427/2-1.

MA 31.11 Wed 18:00 H 0110

Directional couplers for short spin wave generation: magnons and phonons — •Piotr Graczyk, Mateusz Zelent, Jarosław Kłos, and Maciej Krawczyk — Faculty of Physics, Adam Mickiewicz University in Poznan, Umultowska 85, 61-614 Poznan, Poland

New ideas to generate short spin waves and process spin wave signals are very desirable nowadays, due to their potential for high energy efficiency and miniaturization. We present here two mechanisms to achieve this goal: directional dipolar coupling in magnonic crystal and broadband magnetoelastic coupling in the magnonic-phononic system. The former is achieved by grating-assisted resonant dipolar interaction between two ferromagnetic layers separated by some distance. We show by the numerical calculations the efficient energy transfer between layers which may be of co-directional or contra-directional type. Such a system may operate either as a short spin wave generator or a frequency filter. In the latter we investigated the dynamics of magnetoelastic excitations in a system consisting of alternating layers of permalloy and CoFeB. The studied structure is optimized for hybridization of specific spin-wave and acoustic dispersion branches in a broad frequency range. Therefore, a device based on this mechanism may be used for efficient generation of high-frequency broadband spin wave signals.

P. Graczyk, M. Zelent, and M. Krawczyk, arXiv:1710.09138 (2017); P. Graczyk and M. Krawczyk, Phys. Rev. B 96, 024407 (2017); P. Graczyk, J. Kłos and M. Krawczyk, Phys. Rev. B 95, 104425 (2017).

Financial support from NCN Poland grants UMO-2012/07/E/ST3/00538, UMO-2016/21/B/ST3/00452

MA 32: Micromagnetism and computational magnetics

Time: Wednesday 15:00–16:45 Location: H 0112

MA 32.1 Wed 15:00 H 0112

Micromagnetic studies of exchange-biased spherical half shells — •Rico Huhnstock, Meike Reginka, Andreea Tomiţa, Dennis Holzinger, and Arno Ehresmann — Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, Heinrich-Plett-Str. 40, D-34132 Kassel

Magnetic Janus particles show a highly promising dynamical behavior in microfluidic experiments especially if the particles consist of a spherical metallic half shell that exhibits a spatially fixed and directed magnetization due to the exchange bias effect. Understanding the magnetic properties of these half shells becomes a difficult task since the underlying curved geometry heavily influences the configuration of the magnetization distribution in the considered system. Thus, in this work the Python based micromagnetic simulation package Nmag [1] was used in order to compute magnetic equilibrium states of the modeled half shells. The results of parameter studies concerning the influence of different energy and size related contributions will be presented and discussed.

[1] Fischbacher, T., Franchin, M., Bordignon, G., Fangohr, H. (2007), A Systematic Approach to Multiphysics Extensions of Finite-Element-Based Micromagnetic Simulations: Nmag. IEEE Transactions on Magnetics, 43: 2896-2898.

MA 32.2 Wed 15:15 H 0112

The role of longitudinal spin dynamics during magnetisation switching in FePt thin films — •Matthew Ellis, Mario Galante, and Stefano Sanvito — School of Physics and CRANN, Trinity College, Dublin 2, Ireland

$L1_0$ ordered FePt is a magnetic material of great interest for magnetic recording applications due to its large uniaxial anisotropy. Previous ab-initio studies observed that the magnetic moments localised on the Pt atoms arise due to the local exchange field provided by the neighbouring Fe atoms. As such an effective spin Hamiltonian can be derived without the Pt degrees of freedom. However, the applicability of this model in out-of-equilibrium cases where the longitudinal dynamics are important is not clear.

Here, we employ an atomistic spin model that incorporates the longitudinal fluctuations of the spin magnetic moment following the Landau Hamiltonian given by Ma and Dudarev [1]. Using this, we construct a model for $L1_0$ FePt, where the Pt magnetic moment depends linearly on its local exchange field. At temperatures close to the Curie point, we observe that despite a low net magnetisation the local ordering of Fe atoms preserves to magnetic moment of the Pt atoms. Finally, we apply this model to switching in FePt thin films using atom-resolved ab-initio computed spin-transfer torque. Whilst the torque on the Fe atoms is dominant and promotes switching the Pt torque opposes this but the exchange interaction sustains the collinearity in the film.

[1] P.-W. Ma and S. L. Dudarev, Phys. Rev. B 86, 54416 (2012).

MA 32.3 Wed 15:30 H 0112

Spirit: a modern framework for spin dynamics — •Gideon P Müller[1,2], Nikolai Kiselev[1], Stefan Blügel[1], and Hannes Jónsson[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Science Institute of the University of Iceland, VR-III, 107 Reykjavík, Iceland

Spin simulations using atomistic models have great importance in theoretical work on solid state magnetism, as they provide valuable predictions and help interpret experimental data. We present our framework of modern cross-platform computational tools for atomistic spin dynamics providing direct user interaction and powerful real-time visualisations. It is designed to increase scientific productivity by simplifying workflows and to minimize time spent on problem-specific programming. Through live visual feedback and parameter control, the time needed to study and understand properties and dynamics of a system is significantly reduced. Thanks to simplified programming interfaces (C/C++ or Python), time- consuming or repetitive tasks can be executed e.g. on a cluster, as all steps taken in the graphical user interface can be easily reproduced.

The framework is the ideal tool for the simulation of localized magnetic objects, such as magnetic skyrmions, chiral bobbers and complex domain walls. Its capabilities include Landau-Lifshitz-Gilbert dynamics simulations and direct energy minimization, as well as the calculation of minimum energy paths and energy barriers for transitions between states, using the geodesic nudged elastic band method.

MA 32.4 Wed 15:45 H 0112

Experiment, mean field theory and Monte Carlo simulations of the magnetocaloric effect in Pr0.65Sr0.35MnO3 perovskite — •rachid masrour — Cady Ayyed University, National School of Applied Sciences, Safi, Morocco.

Magnetic properties and magnetocaloric effect of the Pr0.65Sr0.35MnO3 perovskite are studied by means experiment, mean field theory and Monte Carlo simulations. The temperature dependence of the magnetic entropy change and of the adiabatic temperature is also obtained. We have used the experiment results, mean field theory and MCSs. The Curie temperature of Pr0.65Sr0.35MnO3 perovskite has been deduced The field dependence of relative cooling power of Pr0.65Sr0.35MnO3 perovskite has been given.

MA 32.5 Wed 16:00 H 0112

ab-initio phase stabilities of Ce-based hard magnetic materials — •halil ibrahim sözen, fritz körmann, tilmann hickle, and jörg neugebauer — Max-Planck-Institut für Eisenforschung, D-40237 Düsseldorf, Germany

Due to the developments in electrical transportation and renewable energies, hard magnetic materials composed of rare earths (RE) and transition metals (TM) have gained increasing importance in the last decades. Recently, there are attempts to develop alternative hard magnetic materials, RE-TM-X (X=Ti, W, Mo, Si, Al), that lift the dependence on a small number of RE elements. In order to support the efforts to find alternative materials concepts for hard magnetic applications, we performed ab initio calculations of finite temperature phase stabilities of Ce-based alloys. The Helmholtz free energy F(T,V) is calculated for all relevant competing phases using a sophisticated set of methods capturing vibrational, electronic, magnetic and configurational entropy contributions. The study includes unary Ce, binaries of Ce-Fe and Fe-Ti phases, and ternary Ce-Fe-Ti phases, for which the performance of our approach for rare-earth metals is tested. Theoretical results are compared with experimental findings. We observe that the presence of the CeFe2 phase retards any formation of promising hard magnetic Ce-Fe-Ti alloys. The study has therefore been extended to the impact of quaternary alloying elements such as Cu, La and Ga, in order to provide strategies to solve this challenge.

MA 32.6 Wed 16:15 H 0112

Macrospin rotation mechanism in discrete and continuum systems. Analytic approach. — •Grzegorz Kwiatkowski — Immanuel Kant Baltic Federal University, Kaliningrad, Russia

Macrospin rotation escape rate is calculated analyticaly for both discrete N-spin and continuous systems with arbitrary potential in harmonic approximation. Method for continuous systems is based on path integral approach to semiclassical quantisation. Influence of material and geometric parameters is discussed and well known limits for macrospin rotation mechanism are explicitly derived.

MA 32.7 Wed 16:30 H 0112

Demagnetazing tensor for two arbitrary oriented uniformly magnetized blocks — •Mikhail Vereshchagin[1], Pavel Bessarab[2], Valerian Yurov[1], and Grzegorz Kwiatkowski[1] — [1]Center for Functionalized Magnetic Materials (FunMagMa), Immanuel Kant Baltic Federal University, 236041 Kaliningrad, Russian Federation. — [2]Department Faculty of Physical Sciences, University of Iceland, Sæmundargötu 2, 101 Reykjavik, Iceland

A classical analytical formula for demagnetization tensor of two uniformly magnetized parallel to each other blocks (Newell et al.(1993)Newell, Williams, and Dunlop) has been generalized for the case when the bodies are oriented arbitrary with respect to each other. Account of arbitrary orientation of the blocks makes computations much more complex and tedious, nevertheless the final formula can be expressed as a sum of several repeated expressions with small differences the similar manner as it is done for parallel blocks' case. The result can be applied for spin ice systems.

MA 33: Biomedical and molecular magnetism

Time: Wednesday 15:00–18:00 Location: H 1012

MA 33.1 Wed 15:00 H 1012

Pictorial description of elementary excitations in ferromagnetic molecular magnets — •Krunoslav Prsa and Oliver Waldmann — Physikalisches Institut, Universität Freiburg, Germany

The common spin-wave approximation of many-body effects in magnetic solids can be used to describe excitations from the ferromagnetic ($S = S_{max}$) ground state in molecular magnets. Starting from the Heisenberg Hamiltonian, both the classical and the quantum approaches provide exact solutions of the transitions from the ground state into the $M = M_{max} - 1$ sector, which are observed in neutron scattering experiments at low temperatures. With the help of the classical approach we infer pictorial descriptions of the magnon wavefunctions similar to the illustrations of the vibrational normal modes in molecules. The magnetic normal modes correspond to a set of standing waves of precession around the polarized ground state. We argue that this representation leads to a better intuitive understanding of the excitations, their symmetry properties, and has links to the energy and wavevector dependence of intensity in the neutron scattering experiments.

MA 33.2 Wed 15:15 H 1012

First principle determination of spin-phonon coupling mechanism in single molecule magnets — •Alessandro Lunghi[1], Federico Totti[2], Roberta Sessoli[2], and Stefano Sanvito[1] — [1]School of Physics, CRANN and AMBER, Trinity College Dublin, Dublin 2, Ireland — [2]Dipartimento di Chimica "Ugo Schiff", Universita' degli studi di Firenze, Sesto F.no, Italy

Single molecule magnets (SMMs) have been extensively investigated for about twenty years and a detailed knowledge of the physical laws at the origin of their static spin properties is now largely achieved. However, still little is known about the microscopic origin of the relaxation processes involved in the spin dynamics. The main interaction responsible for spin relaxation at finite temperature is the spin-phonon coupling and first-principles atomistic theory offers a natural tool to study such interaction. In this contribution, we will present a formalism for the spin-phonon dynamics suitable for its implementation together with post Hartree-Fock and Density Functional Theory calculations. We will illustrate the application of such formalism to describe the spin relaxation of the Fe(tpa)Ph SMM[1]. Results of these simulations will be illustrated with emphasis on the temperature dependence of the spin relaxation [2] and on the nature of the phonons primarily responsible for the relaxation in molecular spin systems [3].

[1] W. H. Harman et al., J.Am.Chem.Soc., 2010, 132, 1224. [2] A. Lunghi, F. Totti, R. Sessoli, S. Sanvito, Nat. Commun., 2017, 8, 14620 [3] A. Lunghi, F. Totti, S. Sanvito. R. Sessoli, Chem. Sci., 2017, 8 (9), 6051-6059.

MA 33.3 Wed 15:30 H 1012

spin-reversal energy barriers of 305 K for Fe^{2+} d^6 ions with linear ligand coordination — •Ziba Zangenehpourzadeh[1], Lei Xu[1], Ravi Yadav[1], Stanislav Avdoshenko[1], Jeroen van den Brink[1], Anton Jesche[2], and Liviu Hozoi[1] — [1]IFW Dresden, Helmholtzstr. 20, 01069 Dresden, Germany — [2]Center for Electronic Correlations and Magnetism, Augsburg University, 86135 Augsburg, Germany

A remarkably large magnetic anisotropy energy of 305 K is computed by quantum chemistry methods for divalent Fe^{2+} d^6 substitutes at Li-ion sites with D_{6h} point-group symmetry within the solid-state matrix of Li_3N. This is similar to values calculated by the same approach and confirmed experimentally for linearly coordinated monovalent Fe^{1+} d^7 species, among the largest so far in the research area of single-molecule magnets. Our *ab initio* results therefore mark a new exploration path in the search for superior single-molecule magnets, rooted in the $d_{xy}^{1.5}d_{x^2-y^2}^{1.5}d_{z^2}^1d_{yz}^1d_{zx}^1$ configuration of d^6 transition-metal ions with linear nearest-neighbor coordination. This d^6 axial anisotropy may be kept robust even for symmetries lower than D_{6h}, provided the ligand and farther-neighbor environment is engineered such that the $d_{xy}^{1.5}d_{x^2-y^2}^{1.5}d_{z^2}^1d_{yz}^1d_{zx}^1 - d_{xy}^1d_{x^2-y^2}^1d_{z^2}^2d_{yz}^1d_{zx}^1$ splitting remains large enough[1].

[1] Nanoscale **9**, 10596 (2017).

MA 33.4 Wed 15:45 H 1012

High Spin Cycles: Topping the Spin Record for a Single Molecule verging on Quantum Criticality — •Jürgen Schnack — Universität Bielefeld, PF 100131, D-33501 Bielefeld

Theory predicts a number of interesting quantum critical phenomena for low-dimensional magnetic systems, where the ground state and thus low-temperature properties of a material change drastically upon even a small variation of an appropriate external parameter. Here we report a mixed 3d/4f cyclic coordination cluster that turns out to be very near or even at such a quantum critical point. The molecule forms a nano-torus with alternating gadolinium and iron ions with a nearest neighbor Fe-Gd coupling and a frustrating next-nearest neighbor Fe-Fe coupling. Such a spin arrangement corresponds to a cyclic delta or saw-tooth chain, which can exhibit a variety of frustration effects, among them giant magnetization jumps as well as macroscopic degeneracies of the ground state with profound caloric consequences. The present cluster is situated on the ferromagnetic side of the Quantum Critical Point with a ground state spin of S=60, which makes it simultaneously the magnetic molecule with the largest total spin ever observed for a magnetic molecule.

MA 33.5 Wed 16:00 H 1012

Magnetic properties of novel single molecule magnets: Lanthanide dimetallofullerenes — •Georgios Velkos, Denis Krylov, Fupin Liu, Lukas Spree, and Alexey Popov — Leibniz Institute for Solid State and Materials Research, Helmholtzstrasse 20, 01069 Dresden, Germany

The encapsulation of two lanthanide atoms inside a fullerene (carbon cage) creates a unique environment for the formation of a single-electron metal-metal bond between the endohedral lanthanide ions. Giant exchange coupling between 4f-based magnetic moments of the lanthanide ions and the spin of an unpaired electron gives a large 'superspin' persistent to room temperature. Single molecule magnetism with large blocking temperature of magnetization has been recently discovered in Dy2@C80. In this work, we further explore the concept of coupling localized magmatic moments of lanthanides via single-electron bond and analyze magnetic properties of dimetallofullerenes with different lanthanides.

MA 33.6 Wed 16:15 H 1012

Electronic Configuration and Charge Transfer in Organometallic Ligand Complexes of Terbium (I, II, III) Ions — •Martin Timm[1], Christine Bülow[1], Vicente Zamudio-Bayer[2], Rebecka Lindblad[3], Bernd von Issendorff[2] und Tobias Lau[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, 12489 Berlin, Germany — [2]Albert-Ludwigs-Universität Freiburg, 79098 Freiburg, Germany — [3]Synkrotronljusfysik, Lunds Universitet, 22100 Lund, Sweden

Complexes of carbocyclic polyene ligands with lanthanoid atoms are of interest because of their large magnetic moments and magnetic anisotropy energy. In many of these complexes, there is a competition between charge transfer to the ligand in order to reach closed electronic shells according to Hückel's (4n + 2) rule, and the preference of lanthanoids to form +III oxidation states. We have, therefore, studied cationic mono- and di-ligated complexes of terbium atoms and cyclic $C_nH_n (n = 5, 6, 8)$ molecules with preferential 0, -1, and -2 charge states by means of X-ray absorption and X-ray magnetic circular dichroism spectroscopy at the terbium $M_{4,5}$ edge. In all cases, we find the $4f^8$ configuration of terbium in its +III oxidation state. Furthermore, x-ray absorption spectra at the carbon K edge of the ligands indicate deviations from their planar ring structures, which is evidence of non-aromaticity.

15 min break

MA 33.7 Wed 16:45 H 1012

Effect of electron doping on Fe_4 single molecule magnets at surfaces — •Fabian Paschke, Vivien Enenkel, Philipp Erler, Luca Gragnaniello, and Mikhail Fonin — Fachbereich Physik, Universität Konstanz, 78457 Konstanz, Germany

The controlled deposition, characterization and manipulation of single molecule magnets (SMMs) on surfaces is one of the crucial topics for their use as units in future electronic and spintronic applications. We recently showed that by using the electrospray deposition of Fe_4H SMMs self-organized arrays on insulating *h*-BN/Rh(111)[1] and graphene/Ir(111)[2] surfaces can be prepared. On graphene/Ir(111) the robustness of the Fe_4 complex is demonstrated as the magnetic anisotropy retains its bulk value despite a non-negligible electronic interaction with the substrate[2]. Here we use scanning tunneling microscopy and spectroscopy as well as x-ray magnetic circular dichroism (XMCD) to investigate the effect of alkali metal (Li) doping on the charge state and magnetic anisotropy of Fe_4H on graphene/Ir(111) and Au(111). Doped molecules show emerging electronic states in the conduction gap and shifted energy positions of molecular orbitals. XMCD measurements indicate substantial changes in the multiplet structure at the Fe *L*-edge, presumably caused by partial reduction of Fe^{3+} to Fe^{2+} in the inorganic core. The magnetic anisotropy of the molecules is shown to be suppressed upon doping with alkali atoms.

[1] P. Erler et al., Nano Lett. 15, 4546 (2015). [2] L. Gragnaniello et al., Nano Lett., 2017, in press.

MA 33.8 Wed 17:00 H 1012

Deposition and selective switching of a cationic Fe(III) compound on Au(111) and Cu_2N — •Manuel Gruber[1], Torben Jasper-Tönnies[1], Sujoy Karan[2], Hanne Jacob[3], Felix Tuczek[3], and Richard Berndt[1] — [1]Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität Kiel — [2]Institute of Experimental and Applied Physics, University of Regensburg — [3]Institut für Anorganische Chemie, Christian-Albrechts-Universität Kiel

Spin-crossover (SCO) complexes contain a transition metal ion that can be switched between a low-spin and a high-spin state by external stimuli. Investigations of single SCO molecules is challenging as the interaction with the substrate often leads to fragmentation or loss of functionality. So far, the focus was on Fe(II) based molecules, while SCO complexes with different metal ions (different oxidation states) would be desirable.

Using scanning tunneling microscopy, we evidence the first successful deposition of a cationic Fe(III) SCO complex, $[Fe(pap)_2]^+$ (pap = N-2-pyridylmethylidene-2-hydroxyphe- nylaminato), on Au(111) and Cu_2N/Cu(100). The deposited Fe(III) SCO compound is controllably switched between three different states, each of them exhibiting a characteristic tunneling conductance. The conductance is therefore employed to readily read the state of the molecules [1,2].

This work was supported by SFB 677.

[1] Jasper-Toennies et al., J. Phys. Chem. Lett. 8, 1569 (2017)
[2] Jasper-Toennies et al., Nano Lett. 17, 6613 (2017)

MA 33.9 Wed 17:15 H 1012

X-ray magnetic spectroscopy study of switchable photomagnetic cages — •Niéli Daffé[1], Michal Studniarek[1], Juan-Ramón Jiménez[2], Rodrigue Lescouëzec[2], and Jan Dreiser[1] — [1]Paul Scherrer Institut, 5232 Villigen PSI, Switzerland — [2]Institut Parisien de Chimie Moléculaire, UPMC, F-75252 Paris, France

Molecules exhibiting switchable physical properties as a function of external stimuli have promising applications in molecule-based electronic devices. Therefore, the past decade has witnessed considerable interest in the design of new molecular systems with tunable functionalities. The most encouraging groups of compounds have emerged from the family of Prussian Blue Analogues (PBAs) that are known to exhibit concomitant changes in their magnetic and optical properties based on a metal-to-metal electron transfer when they are submitted to a temperature or light stimulus (D. Aguilà *et al.*, *Chem. Soc. Rev.* **45**, 203-224, 2016). Molecular cubes based on Co and Fe 3d transition ions linked by cyanide bridges are a prime example of a reversible conversion occurring between the diamagnetic (Fe^{II}_{LS}-CN-Co^{III}_{LS}) pairs and the paramagnetic (Fe^{III}_{LS}-CN-Co^{II}_{HS}) ones (D. Garnier *et al.*, *Chem. Sci.* **7**, 4825-4831, 2016). However, our understanding of the metal-to-metal charge transfer remains one of the key issues faced when studying PBAs, and it requires better insights on the geometry and the nature of the coordinated atoms. Using X-ray absorption spectroscopy and X-ray magnetic circular dichroism, we shed light onto the electronic and magnetic properties of the Co and Fe ions inside the CoFe photomagnetic cage upon temperature change and light irradiation.

MA 33.10 Wed 17:30 H 1012

Magnetite-gold Janus nanoparticles as all-in-one theranostics agents — •Maria V. Efremova[1,2], Yulia A. Nalench[2], Victor A. Naumenko[2], Maxim A. Abakumov[3], Marina Spasova[4], Michael Farle[4], Alexander G. Majouga[1,2,5], Ulf Wiedwald[2,4], and Natalia L. Klyachko[1,2] — [1]MSU, Moscow, Russia — [2]NUST MISIS, Moscow, Russia — [3]RNRMU, Moscow, Russia — [4]UDE, Duisburg, Germany — [5]MUCTR, Moscow, Russia

High-quality, 25 nm octahedral-shaped Fe_3O_4 magnetite nanocrystals are epitaxially grown on 9 nm Au seed nanoparticles (NPs) using a modified wet-chemical synthesis. Detailed studies of the structure and magnetism discover single-crystalline, nanosized Fe_3O_4 NPs with bulk-like magnetic properties (saturation magnetization of 86 Am^2/kg at 300 K close to the bulk value of 92 Am^2/kg and a Verwey transition from monoclinic to the cubic inverse spinel structure at $T_V = 123$ K). For MRI, these features lead to their high T_2-relaxivity in *in vitro* and *in vivo* experiments. We evaluate an at least doubled relaxivity as compared to the maximum values obtained for $Fe_3O_4 - Au$ hybrids and a 3-5 times higher value as compared to commercial T_2 contrast agents in medical use. Moreover, first experiments on the magneto-mechanical action of the hybrid NPs in a low-frequency alternating magnetic field leads to a cell death rate of up to 44% compared to the control.

This work was supported by RFBR 17-54-33027 grant and Increase Competitiveness Programs of NUST MISiS K2-2016-069 (synthesis of nanomaterials) and K3-2017-022 (magnetic measurements).

MA 33.11 Wed 17:45 H 1012

Investigation of uptaking Aminosilane coated magnetite nanoparticles by cells — •m. youhannayee[1], s. nakhaeirad[2], f. haghighi[2], r. ahmadian[2], a. shaaban[3], j. nothacker[3], a. schmidt[3], a. barbian[4], k. klauke[5], c. janiak[5], r. rabenalt[6], p. albers[6], and m. getzlaff[1] — [1]angewandte physik, heinrich-heine universität, Düsseldorf — [2]biochemie molekularbiologie II, HHU — [3]Physikalische Chemie, Universität zu Köln — [4]Anatomie I, HHU — [5]bioanorganische Chemie, HHU — [6]Klinik für Urologie, HHU

The basic principle of hyperthermia for cancer therapy arises from increasing the temperature of the specific organs and tissues from 41 °C to 46 °C[1]. Using magnetic nanoparticles and applying alternating magnetic field (AC) on them is so called as magnetic fluid hyperthermia. In this project superparamagnetic iron oxide nanoparticles (SPION) with functionalized surface Aminosilane around the iron oxide core are applied which have been widely using in different experimental applications in vivo and vitro experiments because of biocompatibility and low toxicity of these particles. In order to characterize the morphological properties of SPION variety of measurements and evaluations were carried out such as transmission electron microscopy (TEM), X-ray diffraction (XRD), Fourier transformed infrared spectroscopy (FTIR). Additionally the effect of AC magnetic field on particles was observed. To investigate the effect of magnetic nanoparticles on cells and their uptaking by cells TEM, MTT measurement and flow cytometry (FACS) were carried out. [1] A. Jordan, R. Scholz, P. Wust, H. Fähling, R. Felix. JMMM 201 (1999): 413-419.

MA 34: Spintronics (joint session MA/TT)

Time: Wednesday 15:00–17:00 Location: EB 202

MA 34.1 Wed 15:00 EB 202

Spin Hall Magnetoresistance in uniaxial antiferromagnet/Pt heterostructures — •Richard Schlitz[1,2], Tobias Kosub[3], Andy Thomas[4], Kornelius Nielsch[4,5], Denys Makarov[3], and Sebastian T.B. Goennenwein[1,2] — [1]Institut für Festkörper- und Materialphysik, TU Dresden, 01062 Dresden, Germany — [2]Center for Transport and Devices of Emergent Materials, TU Dresden, 01062 Dresden, Germany — [3]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [4]Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden), Institute for Metallic Materials, 01069 Dresden, Germany — [5]TU Dresden, Institute of Materials Science, 01062 Dresden, Germany

Antiferromagnets recently attracted a lot of interest as candidate materials for spintronic applications. In this study, we investigate the spin Hall magnetoresistance (SMR) in uniaxial antiferromagnet (AFM)/Pt bilayers. Our results suggest that experiments close to the Neel temperature of the AFM layer allow to study the magnetic phase diagram of the AFM. By rotating the magnetic field in three orthogonal rotation planes, we establish the 3D fingerprint of the SMR also in AFM/Pt heterostructures, giving further insights into the impact of anisotropy and domain pattern. Finally, we propose an extension of the monodomainization model put forward recently in conjunction with measurements on NiO/Pt heterostructures [1] which provides an alternative explanation on the origin of the negative SMR signature.

[1] J. Fischer *et al.*, arxiv:1709.04158 (2017)

MA 34.2 Wed 15:15 EB 202

Current induced Nèel vector manipulation in Mn_2Au and associated giant anisotropic magnetoresistance — •Bodnar Stanislav[1], Šmejkal Libor[1,2,3], Gomonay Olena[1], Sinova Jairo[1], Sapozhnik Alexey[1], Elmers Hans-Joachim[1], Kläui Mathias[1], Filianina Mariia[1], and Jourdan Martin[1] — [1]Mainz University, Staudinger Weg 7, 55128 Mainz, Germany — [2]Institute of Physics, Academy of Sciences of the Czech Republic, Cukrovarnicka 10, 162 00 Praha 6, Czech Republic — [3]Faculty of Mathematics and Physics, Charles University, Department of Condensed Matter Physics, Ke Karlovu 5, 12116 Praha 2, Czech Republic

Antiferromagnetic materials could be used as active elements in spintronics. This requires the ability to switch and read-out the Néel vector state. In our work we demonstrate for Mn_2Au, a good conductor with a high ordering temperature suitable for applications, reproducible switching of the Nèel vector using current pulse generated bulk spin-orbit torques and read-out by magnetoresistance measurements. Reversible and consistent changes of the longitudinal resistance and planar Hall voltage of star-patterned epitaxial $Mn_2Au(001)$ thin films were generated by pulse current densities of 10^7 A/cm^2 . The symmetry of the torques agrees with theoretical predictions and a large read-out magnetoresistance effect of more than 6 % is reproduced by ab initio transport calculations.

MA 34.3 Wed 15:30 EB 202

Granularity Effects in Antiferromagnetic Spintronics Devices — •Tobias Kosub[1], Patrick Appel[2], Brendan Shields[2], Patrick Maletinsky[2], René Hübner[1], Jürgen Lindner[1], Jürgen Fassbender[1], and Denys Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, Dresden, Germany — [2]University of Basel, Basel, Switzerland

Antiferromagnetic thin film systems have recently become an important focus in spintronics as all-electrical writing and reading mechanisms were discovered [1-3]. The early device prototypes have clearly shown that the extrinsic effects of film strain, granularity and non-zero magnetization are decisive factors in actual performance. Such thin film effects do not merely bring about small alterations to the expected behavior, but can indeed make or break functionality.

In this context, we demonstrate two new complementary methods to study the impact of granularity on the magnetism of antiferromagnetic thin films. We show extremely sensitive Zero-Offset Hall measurements of the non-zero magnetization as well as Nitrogen Vacancy Magnetic Microscopy of the domain patterns for Cr_2O_3 thin films.

We can track the magnetic ordering in both real and statistical space and we derive important quantities such as pinning and the intergranular exchange.

[1] T. Kosub et al., *Nature Commun.* **8**, 13985 (2017).
[2] T. Kosub et al., *Phys. Rev. Lett.* **115**, 097201 (2015).
[3] P. Wadley et al., *Science* **351**, 587 (2016).

MA 34.4 Wed 15:45 EB 202

Defect induced magnetism — A framework for all-semiconductor spintronics — •Lukas Botsch[1], Israel Lorite[1], Yogesh Kumar[1], Pablo Esquinazi[1], Tom Michalsky[1], Joachim Zajadacz[2], and Klaus Zimmer[2] — [1]Felix-Bloch-Institute for Solid State Physics, Leipzig University, Germany — [2]Leibniz-Institut für Oberflächenmodifizierung e. V., Leipzig, Germany

Combining the so-called defect induced magnetism (DIM) phenomenon — inducing magnetic order in nominally non-magnetic materials through defects — with acceptor/donor doping in semiconducting materials opens a whole new degree of engineering freedom to design spintronic devices. The DIM phenomenon is known to exist in a variety of materials such as different oxides, nitrides and carbon based materials. We demonstrate the versatility of this framework by showing its application in an all-semiconductor spin-filter device, prepared at the surface of a ZnO microwire by low energy ion implantation. This device is based on a spin-blockade effect that arises at the interface between highly doped magnetic and lightly doped non-magnetic regions at the surface of the wire. The device can be tuned to operate in a large range of temperatures and shows strong spin filtering.

MA 34.5 Wed 16:00 EB 202

p-type co-doping effect in III-Mn-V dilute ferromagnetic semiconductors — •Chi Xu[1,2], Ye Yuan[1,2], Mao Wang[1,2], Roman Böttger[1], Manfred Helm[1,2], and Shengqiang Zhou[1] — [1]Helmholtz-Zentrum Dresden Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstrasse 400, D-01328 Dresden, Germany — [2]Technische Universität Dresden, D-01062 Dresden, Germany

III-Mn-V based diluted magnetic semiconductors offer an opportunity to explore various aspects of carrier transport in the presence of cooperative phenomena. In this work, we demonstrate the efficiency of an alternative approach to control the carrier state through involving one magnetic impurity Mn and one electrically active dopant Zn. Mn-doped and Zn co-doped Ga-V films have been prepared by combining ion implantation and pulsed laser melting, followed by a systematic investigation on the magnetic and transport properties of (Ga,Mn)P by varying Mn concentration as well as by Zn co-doping. Changes of electrical, magnetic and magneto-transport behavior of the investigated Ga-Mn-V films were observed after co-doping with Zn. The changes are caused by interstitial Mn atoms which are transferred from substitutional sites or formation of Mn-Zn dimers.

MA 34.6 Wed 16:15 EB 202

Dynamics of Mn Local Moments in Metallic and Semiconducting Pnictides — M. A. Surmach[1], P. Y. Portnichenko[1], Z. Deng[2,3], C. Q. Lin[2,4,5], J. K. Glasbrenner[6], I. I. Mazin[6], D. L. Sun[7], Y. Liu[7], C. T. Lin[7], A. Ivanov[8], J. T. Park[9], J. A. Rodriguez-Rivera[10,11], and •D. S. Inosov[1] — [1]TU Dresden, Germany — [2]Inst. of Physics, Beijing — [3]Center for High Pressure Sci. & Technol., Beijing — [4]Univ. of Chinese Academy of Sciences, Beijing — [5]Collab. Innov. Center of Quantum Matter, Beijing — [6]Naval Research Lab., Washington, USA — [7]MPI-FKF, Stuttgart, Germany — [8]ILL, Grenoble, France — [9]MLZ, Garching, Germany — [10]Univ. of Maryland, USA — [11]NIST Center for Neutron Research, USA

We have investigated the effects of Mn doping in two materials isostructural to 122-type iron-based superconductors by neutron spectroscopy. First, we discuss the excitation spectrum of Mn-substituted $BaFe_2As_2$, where local magnetic clusters pinned to the impurity sites lead to an emergence of (π,π) magnetic excitations. We discuss their 3D character and the origin of the spin gap. The 2$^{\text{nd}}$ class of materials derives from the isostructural semiconductor $BaZn_2As_2$, giving rise to a dilute magnetic semiconductor upon Mn substitution. Hole doping by K provides an opportunity to tune the carrier concentration and the amount of magnetic moments independently. The resulting compound, $(Ba_{1-x}K_x)(Zn_{1-y}Mn_y)_2As_2$, is a ferromagnet with the maximal Curie temperature of 230 K. It offers a versatility of chemically tailored properties, as the hole doping is decoupled from spin injection and occurs in a different crystallographic layer.

MA 34.7 Wed 16:30 EB 202

Quasiclassical theory of the Rashba-Edelstein magnetoresistance — •Sebastian Tölle[1], Michael Dzierzawa[1], Ulrich Eckern[1], and Cosimo Gorini[2] — [1]Institute of Physics, University of Augsburg, 86135 Augsburg, Germany — [2]Faculty of Physics, University of Regensburg, 93040 Regensburg, Germany

In a recent experiment, a magnetoresistance originating from Rashba spin-orbit coupling in a metallic heterostructure has been observed [1]. We consider a 3D Rashba metal with mass anisotropy [2] attached to a ferromagnetic insulator and employ the quasiclassical approach to derive a set of coupled spin-diffusion equations. Due to the spin transfer torque, the current-induced spin polarization (Edelstein effect) acquires a characteristic dependence on the polarization direction of the ferromagnet which manifests itself as a signature in the magnetoresistance. Our theoretical results reproduce several qualitative features of the experiments. In particular, the Elliott-Yafet spin relaxation plays a major role in explaining the temperature dependence of the observed signature.

[1] H. Nakayama et al., Phys. Rev. Lett. 117, 116602 (2016); H. Nakayama et al., Appl. Phys. Lett. 110, 222406 (2017).
[2] V. Brosco and C. Grimaldi, Phys. Rev. B 95, 195164 (2017).

MA 34.8 Wed 16:45 EB 202

Geometric phase switching in spin interferometry — •Henri Saarikoski[1], Andres Reynoso[2], Diego Frustaglia[3], Jose-Pablo Baltanás[3], Makoto Kohda[4], and Junsaku Nitta[4] — [1]RIKEN Center for Emergent Matter Science, Wako, Saitama 351-0198, Japan — [2]Instituto Balseiro and Centro Atómico Bariloche, 8400 Bariloche, Argentina — [3]Departamento de Física Aplicada II, Universidad de Sevilla, E-41012 Sevilla, Spain — [4]Department of Materials Science, Tohoku University, Sendai 980-8579, Japan

The geometric (Berry) phase acquired by an electron in a cyclic evolution depends on the topology of the driving fields. An oscillating field in the adiabatic limit does not result in a Berry phase in contrast to a rotating field that gives a Berry phase of π. We consider here theoretically topological geometric phase switching in quasi-two-dimensional mesoscopic ring systems where the geometric phase is of nonadiabatic (Aharonov-Anandan) type of geometric phase. The driving field results from interplay between Bychov-Rashba and Dresselhaus [001] spin-orbit fields and an in-plane magnetic field. We find that the geometric phase switching is imprinted both in the resistance as well as in anisotropy oscillations of the ring. We compare results with experiments in circular and polygonal ring systems.

MA 35: Skyrmions III (joint session MA/TT/KFM)

Time: Wednesday 15:00–18:30 Location: EB 301

MA 35.1 Wed 15:00 EB 301

Skyrmion drag effect: — •Adel Abbout[1], Joseph Weston[2], Xavier Waintal[2], and Aurelien Manchon[1] — [1]King Abdullah University of Science and Technology (KAUST), Thuwal, Saudi Arabia — [2]CEA Grenoble, France.

In this work, we study the motion of skyrmionic magnetic textures and analyze the current induced by this motion using time-dependent nonequilibrium Green's function formalism implemented on a real-space tight-binding model. We focus on the time dependent distribution of the nonequilibrium charge and spin densities and discuss the corresponding topological Hall effect. The perturbation induced by this motion applies a torque on the whole texture. The influence of the generated current on the whole texture is discussed and its signature is unveiled in the renormalization of the damping parameter. A cooperative effect due to the collective motion of skyrmions is proposed in order to enhance the skyrmion's velocity. The stationary regime is analyzed as a function of the different parameters of the system and explained using the formalism of electronic pumping. A simple formula for the current is proposed.

MA 35.2 Wed 15:15 EB 301

Theory of tunneling vector spin transport on a magnetic skyrmion — •Krisztián Palotás[1,2], Levente Rózsa[3], and László Szunyogh[4] — [1]Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia — [2]University of Szeged, Szeged, Hungary — [3]University of Hamburg, Hamburg, Germany — [4]Budapest University of Technology and Economics, Budapest, Hungary

Spin-polarized scanning tunneling microscopy (SP-STM) demonstrated the creation and annihilation of individual magnetic skyrmions [1] that is promising for future technological use. The detailed microscopic mechanisms for these processes are, however, unknown. In the present work the tunneling spin transport of a magnetic skyrmion is theoretically investigated in SP-STM. The spin-polarized charge current [2] and tunneling spin transport vector quantities, the longitudinal spin current and the spin transfer torque are calculated in high spatial resolution within a simple electron tunneling theory for the first time. Beside the vector spin transport characteristics, the connections between conventional charge current SP-STM images and the magnitudes of the spin transport quantities are analyzed.

[1] N. Romming et al., Science 341, 636 (2013).
[2] K. Palotás et al., Phys. Rev. B 96, 024410 (2017).

MA 35.3 Wed 15:30 EB 301

Quantum dynamics of skyrmions in chiral magnets — •Christina Psaroudaki — Department of Physics, University of Basel, Klingelbergstrasse 82, CH-4056 Basel, Switzerland

We study the quantum propagation of a skyrmion in chiral magnetic insulators by generalizing the micromagnetic equations of motion to a finite temperature path integral formalism, using field theoretic tools. Promoting the center of the skyrmion to a dynamic quantity, the fluctuations around the skyrmionic configuration give rise to a time-dependent damping of the skyrmion motion. From the frequency dependence of the damping kernel, we are able to identify the skyrmion mass, thus providing a microscopic description of the kinematic properties of skyrmions. When defects are present or a magnetic trap is applied, the skyrmion mass acquires a finite value proportional to the effective spin, even at vanishingly small temperature. We demonstrate that a skyrmion in a confined geometry provided by a magnetic trap behaves as a massive particle owing to its quasi-one dimensional confinement. An additional quantum mass term is predicted, independent of the effective spin, with an explicit temperature dependence which remains finite even at zero temperature.

MA 35.4 Wed 15:45 EB 301

Optimizing the size of long-lived magnetic skyrmions — Anastasiya Varentsova[1], Stephan v. Malottki[2], Stefan Heinze[2], and •Pavel F. Bessarab[1,3] — [1]ITMO University, St. Petersburg, Russia — [2]University of Kiel, Kiel, Germany — [3]University of Iceland, Reykjavik, Iceland

Available experimental data on magnetic skyrmions in various materials demonstrate inverse correlation between the skyrmion size and skyrmion stability: small skyrmions tend to be less stable compared to large ones [1,2]. The question arises how fundamental this trend is and whether it is possible to obtain long-lived magnetic skyrmions at ambient conditions while keeping their size at the nanoscale.

Here, we demonstrate by means of transition state theory [3] and minimum energy path calculations [4] that the skyrmion lifetime at a given temperature is not a unique function of the skyrmion size and that it is possible to systematically tune material parameters so as to minimize the size of skyrmions while keeping their stability at a desired level. Based on this analysis we identify the most promising materials for the use as storage media based on magnetic skyrmions.

[1] W. Jiang *et al.*, Science **349**, 283 (2015).
[2] N. Romming *et al.*, Science **341**, 636 (2013).
[3] P.F. Bessarab *et al.*, Phys. Rev. B **85**, 184409 (2012).
[4] P.F. Bessarab *et al.*, Comput. Phys. Commun. **196**, 335 (2015).

MA 35.5 Wed 16:00 EB 301

Critical Phenomena in Confined Skyrmion Systems — •Jonathon Waters[1], Timothy Sluckin[1], Denis Kramer[1], Hans Fangohr[2], and Ondrej Hovorka[1] — [1]University of Southampton,

Southampton, UK — [2]European XFEL, Germany

There have been extensive studies which establish the magnetic phases and quantify the thermal phase transition behaviour in bulk helimagnetic materials. However, many proposed device applications, which will utilise the skyrmion phase of these materials, are expected to assume operation in confined geometries and, therefore, it is critical to access the role of the confinement and finite size effects on the stability of skyrmion phases. So far, there have been few studies aimed at understanding the finite system size effects on the thermal phase transition behaviour in these systems. This presentation will discuss our recent developments of systematic analysis of these fundamental effects.

We present large-scale Monte-Carlo simulations of cubic nanoparticles, modelled by a general Heisenberg model with Dzyaloshinskii-Moriya interaction (DMI), and establish phase diagrams for different combinations of exchange and DMI strengths. We apply several different annealing protocols when generating the phase diagram in order to establish the role of metastability and hysteresis in the phase behaviour of these systems. Finally we discuss the results of a finite system size scaling analysis and establish the dependence of critical phase transition temperature on the particle size.

MA 35.6 Wed 16:15 EB 301

Magnetic skyrmion dynamics in thin cylindrical nanodots — •Konstantin Guslienko[1,2] and Zukhra Gareeva[3] — [1]Depto. Física de Materiales, Universidad del País Vasco, UPV/EHU, 20018 San Sebastián, Spain — [2]IKERBASQUE, the Basque Foundation for Science, 48013 Bilbao, Spain — [3]Institute of Molecule and Crystal Physics, Russian Academy of Sciences, 450075 Ufa, Russia

Magnetic skyrmions, robust particle-like nanosize objects, attracted considerable attention due to promising applications in spintronics and information technologies. Being a kind of magnetic topological solitons in 2D spin systems, skyrmions exhibit a wide variety of unusual properties related to their topology. In this talk we focus on the low and high frequency dynamics of magnetic skyrmions in the systems of restricted geometry: isolated cylindrical nanodots. We consider Bloch- and Neel skyrmions as the ground magnetic state of thin circular nanodots stabilized due to an interplay of the isotropic and Dzyaloshinskii-Moriya exchange interactions, perpendicular magnetic anisotropy and magnetostatic interaction. We calculate spectrum of spin excitations over the skyrmion background and classify the eigenmodes according to their spatial symmetry. We show that only one gyrotropic mode (rotation of the skyrmion center position with the frequency about of 1 GHz) exists for the skyrmion of definite polarity and the other low frequency modes that are observed in the skyrmion excitation spectra correspond to spin waves. We found an asymmetry between azimuthal spin waves propagating in the clockwise and counter-clockwise directions that is closely related to the skyrmion topology.

MA 35.7 Wed 16:30 EB 301

Internal structure and stability of skyrmions in ferromagnet/heavy-metal multilayers — •Ksenia Chichay[1], Joseph Barker[2], and Oleg Tretiakov[2,3] — [1]Center for Functionalized Magnetic Materials (FunMagMa), Immanuel Kant Baltic Federal University, Kaliningrad, Russia — [2]Institute for Materials Research, Tohoku University, Sendai, Japan — [3]School of Natural Sciences, Far Eastern Federal University, Vladivostok, Russia

Magnetic Skyrmions are one of the fascinating and promising objects because of their small size and stability to perturbations such as electric currents and magnetic fields. The major mechanism to stabilize small skyrmions in ferromagnet/heavy-metal bilayers is the presence of Dzyaloshinskii-Moriya interaction (DMI).

In this work we investigate the stability and internal structure of an isolated skyrmion in bilayer (ferromagnet/heavy metal) and trilayer (heavy metal 1/ferromagnet/heavy metal 2) nanodisks. We study the static properties of the skyrmions and obtain the phase diagrams of the skyrmion existence depending on the thickness of the ferromagnetic layer and the DMI strength. We demonstrate the importance of fully taking into account the dipolar interaction even for a few atomic layers thin nanodisk and that together with DMI it has the stabilizing effect and defines the Skyrmion configuration. For the trilayer structures with two heavy-metal interfaces, we show that the type and configuration of the skyrmion can be controlled by the thickness of ferromagnet. Furthermore, the interplay of two interfacial DMIs can lead to the formation of magnetic structures with higher winding number.

MA 35.8 Wed 16:45 EB 301

Skyrmion dynamics under the influence of defects from DFT to ASD — •Jonathan Chico, Imara Lima Fernandes, Stefan Blügel, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Any potential skyrmionic application must be able to handle the impact of defects on the movement of skyrmions. Until now, most approaches focussed on large skyrmions and thus phenomenological schemes in the micromagnetic regime. In this work we discuss the technologically much more promising small skyrmions.

Using a combination of first-principles calculations and atomistic spin dynamics, the motion of small skyrmions in Pd/Fe/Ir(111) with $3d$ and $4d$ atomic defects is studied. In general, two types of defects are found, attractive and repulsive [1]. It can be observed that depending on the chemical nature of the defect the current threshold needed to overcome the energy barriers, resulting from the impurities, varies. The obtained dynamical behaviour is richer than what is expected from the Thiele equation. The complexity of the different motion regimes are revealed and compared with what is known for larger skyrmions. The present study also shines light on how one can engineer defects-based pathways for controlled skyrmion motion.

[1] I. L. Fernandes *et al.* submitted (2017).

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

MA 35.9 Wed 17:00 EB 301

First-principles study of skyrmion formation at $3d/4d$ transition-metal interfaces — •Soumyajyoti Haldar[1], Stephan von Malottki[1], Pavel F. Bessarab[2], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel, 24098, Kiel, Germany — [2]School of Engineering and Natural Sciences, University of Iceland, 107, Reykjavik, Iceland

Typically, it is assumed that for the formation of skyrmions with a diameter of a few nanometers a $3d/5d$ transition metal (TM) interface is required due to the large spin-orbit coupling of heavy TMs which leads to large Dzyaloshinskii-Moriya interaction (DMI). Here, we use density functional theory (DFT) as implemented in the FLEUR code [1] to demonstrate that ultrasmall skyrmions can also emerge at $3d/4d$ TM interfaces. We have calculated the magnetic interactions in atomic bilayers of Pd/Fe on the Rh(111) surface – a system which is similar to Pd/Fe/Ir(111) [2, 3] since Rh and Ir are isoelectronic $4d$- and $5d$-TMs. From our DFT calculations we parametrize an atomistic spin model including exchange interactions, DMI and the magnetocrystalline anisotropy energy (MAE). We find that both DMI and MAE are reduced with respect to Pd/Fe/Ir(111) which still allows a spin spiral phase at zero magnetic field due to DMI. Using spin dynamics simulations we find that a skyrmion phase occurs for both fcc and hcp stacking of the Pd layer at small magnetic fields of ~ 1 T. Depending on the stacking the skyrmion diameters amount to 4 to 6 nm.

[1] http://www.flapw.de [2] N. Romming *et al.*, Science **341**, 6146 (2013) [3] B. Dupé *et al.*, Nature Comm. **5**, 4030 (2014).

MA 35.10 Wed 17:15 EB 301

Frustration of the Dzyaloshinskii-Moriya interaction in ultrathin Co films — •Sebastian Meyer[1], Stephan Von Malottki[1], Bertrand Dupé[2], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, Leibnizstrasse 15, 24098 Kiel — [2]Institute of Physics, Johannes Gutenberg Universität Mainz, Staudingerweg 7, 55128 Mainz

Non-collinear spin structures such as chiral domain walls and skyrmions are being intensively studied since they are promising for spintronic applications [1, 2]. The Dzyaloshinskii-Moriya interaction (DMI) is crucial for stabilizing these non-trivial magnetic states favoring a unique rotational sense. Here, we show frustration of the DMI in ultrathin Co films using density functional theory (DFT) as implemented in the FLEUR code [3]. We study Co monolayers and Pt/Co bilayers on the Ir(111) surface and calculate the energy dispersion of homogeneous flat spin spirals including spin-orbit coupling. Clockwise rotating spin spirals are preferred for large periods close to the ferromagnetic state while below a certain spin spiral period an anticlockwise sense is obtained. This effect arises due to competing DMI interactions with different neighbors that are of opposite sign. With our results from DFT, we parametrize an atomistic spin model and simulate domain wall properties using spin-dynamics simulations.

[1] S. S. P. Parkin *et al.*, Science **320**, 190 (2008)
[2] A. Fert *et al.*, Nature Nano. **8**, 152 (2013)

[3] www.flapw.de

MA 35.11 Wed 17:30 EB 301

Isolated skyrmions with vanishing anisotropy in Co/Ru(0001) — •Marie Böttcher[1,2], Marie Hervé[3], Jairo Sinova[1,4], Wulf Wulfhekel[3], and Bertrand Dupé[1] — [1]Johannes Gutenberg-Universität Mainz, Mainz, Germany — [2]Graduate School Materials Science in Mainz, Mainz, Germany — [3]Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany — [4]Academy of Sciences of the Czech Republic, Praha, Czech Republic

Magnetic skyrmions are localized and topologically stabilized noncollinear spin structures. They offer attractive perspectives for future spintronics applications, because they can be manipulated at lower current densities than domain walls [1]. The stabilization of skyrmions is usually attributed to a large Dzyaloshinskii-Moriya interaction (DMI). Here, we show that a strong DMI is not a necessary condition to obtain skyrmions in ultra-thin films. Co/Ru(0001) possesses a spin spiral ground state, although the DMI is weak. We attribute the stability of this spin texture to the simultaneous vanishing of anisotropy [2]. We determine the B-T phase diagram for this system using Monte Carlo simulations and show the magnetic field dependence of isolated skyrmions at magnetic fields with a ferromagnetic ground state. [1] A. Fert, *et al.* Nature Nano. **8**, 152 (2013). [2] M. Hervé *et al.* arXiv:1707.08519 (2017)

MA 35.12 Wed 17:45 EB 301

Magnetic skyrmions in curvilinear films — •Volodymyr Kravchuk[1,2], Denis Sheka[3], Attila Kakay[4], Oleksii Volkov[4], Ulrich Roessler[1], Jeroen van den Brink[1], Denys Makarov[4], and Yuri Gaididiei[2] — [1]Leibniz-Institut fuer Festkoerper- und Werkstoffforschung, D-01171 Dresden, Germany — [2]Bogolyubov Institute for Theoretical Physics of National Academy of Sciences of Ukraine, 03680 Kyiv, Ukraine — [3]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine — [4]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Topological magnetic solitons on curvilinear magnetic films acquire new properties if the curvature radius is comparable with the size of the soliton. Earlier we demonstrated [1] that ferromagnetic skyrmions can be stabilized due to the curvature effects only without intrinsic chiral magnetic interactions. However, the curvature induced skyrmion is an excitation of the ground state, as well as a skyrmion in a planar film. Here we show that the combined action of the curvature and the chiral interaction can make skyrmion the ground state of the system [2]. Moreover, ferromagnetic skyrmion pinned on a curvilinear defect demonstrates a discrete set of equilibrium states. Transitions between different states can be controlled by external magnetic field. Thus, the periodically arranged curvilinear defects can result in a reconfigurable skyrmion lattice. This opens new perspectives on processing and storing of the information.

[1] V. Kravchuk et al., BRB 94, 144402 (2016). [2] V. Kravchuk et al., arXiv 1706.05653 (2017).

MA 35.13 Wed 18:00 EB 301

Skyrmion-Lattice Collapse and Defect-Induced Melting in Chiral Magnetic Films — •Leonardo Pierobon[1], Christoforos Moutafis[2], Michalis Charilaou[1], and Jörg Löffler[1] — [1]Laboratory of Metal Physics and Technology, Department of Materials, ETH Zurich, Switzerland — [2]School of Computer Science, University of Manchester, Manchester, UK

Complex spin textures arise in nanostructured magnets due to competing interactions, primarily the Heisenberg exchange and the Dzyaloshinskii-Moriya interaction (DMI), which promote spin collinearity and canting, respectively. Upon rotational-symmetry breaking, particle-like objects with non-trivial spin configurations, i.e., skyrmions, can be created. The winding of skyrmions bestows a topological protection on the system, and the transition to the topologically trivial ferromagnetic state requires a phase transition. Here, we systematically compare isotropic and anisotropic DMI systems by means of high-resolution numerical simulations. We show that in perfect systems skyrmion lattices can be inverted in a field-induced first-order phase transition, whereas the existence of even a single defect replaces the inversion with a second-order phase transition following a defect-induced lattice melting process. This radical qualitative change signifies the importance of employing such an analysis for all realistic systems in order to correctly interpret experimental data. Our results shed light on fundamental processes behind magnetic phase transitions, and pave the way for their experimental realization in technologically relevant multilayer materials.

MA 35.14 Wed 18:15 EB 301

Reservoir Computing with Random Skyrmion Fabrics — •Daniele Pinna[1], George Bourianoff[2], and Karin Everschor-Sitte[1] — [1]Institute of Physics, Johannes Gutenberg University Mainz, Mainz, Germany — [2]Intel Labs, Intel Corp, Austin, TX

Thanks to their many nanoscale properties, skyrmions are promising in applications ranging from non-volatile memory[1] and spintronic logic devices[2], to enabling the implementation of unconventional computational standards[3, 4]. In this talk we will discuss how a random skyrmion "fabric" composed of skyrmion clusters embedded in a magnetic substrate can be effectively employed to implement a functional reservoir computer. This is achieved by leveraging the nonlinear resistive response of the individual skyrmions arising from their current dependent AMR[5]. Complex time-varying current signals injected via contacts into the magnetic substrate are shown to be modulated nonlinearly by the fabric's AMR due to the current distribution following paths of least resistance as it traverses the geometry. By tracking resistances across multiple input and output contacts, we show how the instantaneous current distribution, reminiscent of Atomic Switch Networks, effectively carries temporally correlated information about the injected signal. This in turn allows us to numerically demonstrate simple pattern recognition.

[1] A. Fert, et al., Nature Nanotech. 8, 152-156 (2013). [2] X. Zhang, et al., Sci. Rep. 5, 9400 (2015). [3] D. Pinna, et al., arXiv:1701.07750 (2017). [4] G. Bourianoff, et al., arXiv:1709.08911 (2017). [5] D. Prychynenko, et al., arXiv:1702.04298 (2017).

MA 36: Topological insulators and Weyl semimetals (joint session MA/TT)

Time: Wednesday 15:00–18:15 Location: EB 407

MA 36.1 Wed 15:00 EB 407

Topological Phase Transitions from Relativistic Many-Body Calculations — •Irene Aguilera, Christoph Friedrich, and Stefan Blügel — Peter Grünberg Institute and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany.

We discuss topological phase transitions (TPTs) on the basis of relativistic *GW* and quasiparticle self-consistent *GW* (QS*GW*) calculations where the spin-orbit coupling is incorporated directly into the self-energy. TPTs can be caused by the variation of the thickness of a sample, the spin-orbit strength, alloying, strain, etc. The well known underestimation of band gaps in standard DFT translates into an overestimation of the inverted band gaps that are responsible for the topological character of materials. This results in standard DFT being unable to provide correctly the critical points of TPTs. As practical examples, we concentrate on semimetals Bi and Sb. In addition to the TPT that bismuth undergoes under strain [1], we discuss that a thickness-mediated TPT can also occur. This sheds light on the discrepancies about the topological or trivial character of bulk-like samples of Bi. Finally, we simulate $Bi_{1-x}Sb_x$ alloys varying the Sb concentration in order to find the critical concentration for which the system becomes a topological insulator.

[1] I. Aguilera *et al.*, Phys. Rev. B **91**, 125129 (2015).

Financial support from the Virtual Institute for Topological Insulators of the Helmholtz Association.

MA 36.2 Wed 15:15 EB 407

High throughput screening of two dimensional topoloigical insulators — •Xinru Li[1], Zeying Zhang[1,2], and Hongbin Zhang[1] — [1]Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany — [2]Beijing Key Laboratory of Nanophotonics and Ultrafine Optoelectronic Systems, School of Physics, Beijing Institute of Tech-

nology, Beijing 100081, China

Topological insulators (TIs), with insulating band gaps and nontrivial edge states, have been widely investigated not only for its fundamental importance but also owing to its potential technological applications. The two-dimensional (2D) TIs are particularly interesting, as they can get easily implemented into devices. There have been many 2D TIs predicted theoretically or synthesized experimentally. However previous efforts have relied mostly on time-consuming trial-and-error procedures. Here, starting from a 2D materials database with 826 slab systems predicted to be stable, we performed high-throughput screening over all materials at the first principles level. For nonmagnetic 2D materials with small (< 0.1 eV)band gaps, maximally localized Wannier functions are constructed in an automated way in order to characterize the topological character by examining the surface states. Combined with explicit evaluation of the topological invariants, we have successfully identified one novel 2D TI, whose topological properties will be discussed in detail.

MA 36.3 Wed 15:30 EB 407

Classification of topological antiferromagnets for spintronics — •Libor Šmejkal[1,2], Jairo Sinova[1,2], and Tomáš Jungwirth[2] — [1]INSPIRE group, Uni Mainz, Germany — [2]Institute of Physics, Czech Academy of Sciences, Prague, Czech Rep.

Our recent prediction of the interplay between topological Dirac quasiparticles and spin orbit torques in antiferromagnets has opened new possibilities of studying topological spintronics [1]. In this talk we will classify topological antiferromagnets based on minimal models, present new material candidates and novel magneto-transport effects, e.g. tunable topological anisotropic magnetoresistance or quantum anomalous Hall effect. The presence of topological quasiparticles can lead to a large signal/noise ratios and novel functionalities in read-out signals in spintronics devices [2]. For example, based on ab initio theory, we have predicted a large anisotropic magnetoresistance reaching 6% in Mn2Au antiferromagnet which was recently observed in current induced torques experiments [3]. We will also demonstrate that antiferromagnets are natural candidates for combining magnetic order with topological Dirac quasiparticles owing to their unique effective time-reversal symmetries, which are not present in ferromagnets [1,2].

[1] L. Šmejkal, J. Železný, J. Sinova, and T. Jungwirth, Phys. Rev. Lett. 118 , 106402 (2017) [2] L. Šmejkal, Y. Mokrousov, B. Yan, and A. H. MacDonald, arXiv:1706.00670 [3] S. Yu. Bodnar, L. Šmejkal, M. Jourdan, et al. arXiv:1706.02482

MA 36.4 Wed 15:45 EB 407

Edelstein effect in Weyl semimetals — •Annika Johansson[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

Using semiclassical Boltzmann transport theory, we predict a current-induced spin polarization in Weyl semimetals, similar to the Edelstein effect of surface states in Rashba systems or in topological insulators [1]. The theory is applied to the Weyl semimetal TaAs simulated by an effective two-band model [2,3], for which we estimate the magnitude of the effect. The main contribution comes from the topological surface states, i. e. the Fermi arcs, which provide an enormous current-induced spin polarization.

[1] V. M. Edelstein, Solid State Commun., **73**, 233 (1990) [2] S. Murakami and S.-i. Kuga, Phys. Rev. B **78**, 165313 (2008) [3] R. Okugawa and S. Murakami, Phys. Rev. B **89**, 235315 (2014)

MA 36.5 Wed 16:00 EB 407

Ferro- and ferrimagnetic coupling in Cr/Bi_2Se_3(0001) — •Andrey Polyakov[1], Katayoon Mohseni[1], E. Daryl Crozier[2], Manuel Valvidares[3], Victor N. Antonov[1], Lev V. Bekenov[1], Arthur Ernst[4], Holger L. Meyerheim[1], and Evgueni V. Chulkov[5] — [1]MPI für Mikrostrukturphysik, Weinberg 2, D-06120 Halle, Germany — [2]Department of Physics, SFU Burnaby, BC Canada, V5A 1S6 — [3]Alba Synchrotron, 08290 Cerdanyola del Valles Barcelona, Spain — [4]Institut für Theoretische Physik, Johannes Kepler Universität, A 4040 Linz, Austria — [5]DIPC, 20018 San Sebastian/Donostia, Basque Country, Spain

Using surface x-ray diffraction, x-ray absorption fine structure and x-ray magnetic circular dichroism experiments in combination with ab-initio calculations we have studied the atomic and magnetic structure of ultra-thin Cr films deposited in the 0.2 to 2.5 monolayer thickness regime on Bi_2Se_3(0001). We find a complex pattern of different adsorption sites (substitutional, van-der Waals gap, and surface double layer formation) involving ferro- and ferri-magnetic exchange. Magnetic moments are close to $4\mu_B$ related to Cr^{2+}. Our study sheds new light on the understanding of magnetic doped topological insulators. Acknowledgements: Supported by SPP 1666. Work at the APS is supported by the U.S. DOE under Contract No. DE-AC02-06CH11357.

MA 36.6 Wed 16:15 EB 407

Circular-polarized-light induced spin characterization of Dirac-cone surface state at W(110) — •Koji Miyamoto[1], Henry Wortelen[2], Taichi Okuda[1], Jürgen Henk[3], and Markus Donath[2] — [1]HSRC, Japan — [2]WWU Münster, Germany — [3]MLU, Germany

Recently, for the topological surface state (TSS) of Bi_2Se_3, several groups have observed an interesting phenomenon by spin- and angle-resolved photoemission (SARPE): the observed spin features of the photoelectrons are strongly dependent on the light polarization [1]. This effect is currently highly debated in the field of optospintronics. So far, the observations of the effect are limited to surfaces with C_{3v} symmetry.

The surface of W(110) shows a spin-polarized Dirac-cone-like state within a spin-orbit-induced gap, which is reminiscent of a TSS [2]. Here, in contrast to so-far studied topological insulators, the surface structure has C_{2v} symmetry.

We studied spin feature of the Dirac-cone-like surface state along $\overline{\Gamma H}$ at W(110) by using SARPE with left and right circular polarized light. It is found that the observed spin textures is caused by spin dependent matrix element influenced by C_{2v} symmetry. This finding opens a new way to manipulate the spin polarization of photoelectron in systems with C_{2v} symmetry.

*[1] C. Jozwiak *et al.*, Nat., Phys. **9**, 293 (2013).
*[2] K. Miyamoto *et al.*, Phys. Rev. Lett. **108**, 066808 (2012).

MA 36.7 Wed 16:30 EB 407

Magnetization-direction tunable nodal-line and Weyl phases — •Zeying Zhang[1,2], Qiang Gao[2], ChengCheng Liu[1], Yugui Yao[1], and Hongbin Zhang[2] — [1]Beijing Key Laboratory of Nanophotonics and Ultrafine Optoelectronic Systems, School of Physics, Beijing Institute of Technology, Beijing 100081, China — [2]Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany

Emergent phenomena in materials with nontrivial topological nature have attracted intensive attention recently, as observed in both 2D and 3D topological insulators. From the symmetry point of view, nodal-line and Weyl semimetals are of particular interest, and they host intriguing properties such as negative magneto-resistance. In this work, we investigate a symmetry based three-band tight-binding model, after consider spin-orbit coupling (SOC) and different magnetization-directions, it is confirmed that the number of Weyl points and nodal line can be tuned by the magnetization direction. It is observed that the mirror symmetry plays a crucial role in protecting the degeneracy of nodal-lines. We propose a new class of materials C_4CrX_3 (X=Ge and Si) which host such a nontrivial semi-metallic phase. The systems have neither spatial inversion nor time reversal symmetries, but surprisingly it is observed that both Weyl points and nodal-lines exist in the ferromagnetic ground state. The degeneracy of nodal-lines can be controlled by the magnetization direction after considering SOC, confirmed by first-principles calculations.

15 min. break.

MA 36.8 Wed 17:00 EB 407

Topological jumps in a finite-size Dzyaloshinskii-Moriya antiferromagnetic chain — •Jaroslav Chovan[1,2] and Dominik Legut[1] — [1]IT4Innovations National Supercomputing Center VSB - Technical University Ostrava, CZ 708 33 Ostrava, Czech Republic — [2]Department of Physics, Matej Bel University, Banska Bystrica, Slovakia

Recently, experiments with thin films of chiral ferromagnets MnSi and $CrNbS_6$ observed sudden jumps in magnetoresistence and/or magnetization induced by a magnetic field applied perpendicularly to the chiral axis. Subsequent theory traced the origin of these jumps to a field-induced transitions between topological sectors with different number of magnetic solitons and established the importance of boundary conditions. Here, we explore the topic in the context of a two-sublattice antiferromagnet. We thus carry out a detailed calculation of magnetic properties of a finite Heisenberg antiferromagnetic chain with

Dzyaloshinskii-Moriya interactions in the presence of external magnetic field. By comparing the energies of magnetic solitons from different topological sectors, we calculate the ground state dependence on the chain size N and the field H. We construct a phase diagram and analyze the topological jumps between the individual sectors in detail and discuss ambiguity in counting the number of magnetic solitons for even-number spin chain. Our results may guide future experiments.

This work was supported by Czech Science Foundation grant No. 17-27790S, project No. CZ.02.1.01/0.0/0.0/16_013/0001791, and Slovak Grant VEGA No. 1/0269/17.

MA 36.9 Wed 17:15 EB 407

Impact of in-gap states on the magnetic stability/excitations of dopants in topological insulators — •Juba Bouaziz, Julen Ibanez-Azpiroz, Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Doping topological insulators with magnetic impurities breaks time reversal symmetry, leading to the prediction of a gap opening at the Dirac point when the magnetic moments are along the *c*-axis [1]. This could potentially functionalize the topological surface states by enabling control of the quantum anomalous Hall effect and dissipationless transport. Several investigations obtained conflicting results, generating a lot of controversy on this point. Since the orientation of the magnetic moments depends on their magnetic anisotropy energy, we use first-principles calculations to investigate isolated 3d and 4d transition metal impurities on the surfaces and in the bulk of Bi_2Te_3 and Bi_2Se_3. We explore the impact of impurity-induced in-gap states on the orientation of the magnetic moments, their dynamical spin-excitations and on the zero-point spin-fluctuations affecting the magnetic stability [2]. We propose to use scanning tunneling spectroscopy in the inelastic mode or in the electron spin resonance mode to verify our predictions. – Funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator grant 681405 - DYNASORE).

[1] Y. L. Chen et *al.*, Science. **329**, 659 (2010).
[2] J. I. Azpiroz et *al.*, Nano Lett. **16**, 4305 (2016).

MA 36.10 Wed 17:30 EB 407

Prediction of a magnetic Weyl semimetal with strong anomalous Hall and Nernst effect in the Heusler compensated ferrimagnet Ti_2MnAl — •Jonathan Noky[1], Wujun Shi[1,2], Lukas Müchler[3], Kaustuv Manna[1], Yang Zhang[1,4], Klaus Köpernik[4], Roberto Car[3], Jeroen van den Brink[4], Claudia Felser[1], and Yan Sun[1] — [1]Max Planck Institute for Chemical Physics of Solids, D-01187 Dresden, Germany — [2]School of Physical Science and Technology, ShanghaiTech University, Shanghai 200031, China — [3]Department of Chemistry, Princeton University, Princeton, New Jersey 08544, USA — [4]Leibniz Institute for Solid State and Materials Research, 01069 Dresden, Germany

We predict the inverse Heusler compound Ti_2MnAl, which is a compensated ferrimagnet with a Curie temperature of over 650 K, to be a magnetic Weyl semimetal. Despite the vanishing net magnetic moment, we calculate a large intrinsic anomalous Hall (AHE) and anomalous Nernst (ANE) effect. These effects stem directly from the Berry curvature distribution of the Weyl points, which are only 14 meV away from the Fermi level and isolated from trivial bands. Since spin-rotation symmetry is broken by the magnetic structure, the Weyl points are stable also without spin-orbit coupling. Additionally, because Weyl points of opposite topological charge show a large spatial separation, this system exhibits huge Fermi arcs.

Ti_2MnAl and, to a lesser extend, also Ti_2MnGa and Ti_2MnIn are first examples of systems with Weyl points, large AHE, and large ANE in spite of a vanishing net magnetic moment.

MA 36.11 Wed 17:45 EB 407

Magnetic Weyl Semimetal in Quasi Two-dimensional Half Metallic $Co_3Sn_2S_2$ and $Co_3Sn_2Se_2$ — •Qiunan Xu[1], Enke Liu[1], Lukas Muechler[2], Claudia Felser[1], and Yan Sun[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden 01187 , Germany — [2]Department of Chemistry, Princeton University, Princeton, New Jersey 08544, USA

A Weyl semimetal can exist in a time reversal or inversion symmetry breaking system. Since the Berry curvature is odd under time reversal, the Berry curvature from Weyl points are expected to generate a large anomalous Hall effect in time reversal symmetry breaking Weyl semimetals. Since the Weyl points are far away from Fermi energy for most of the candidate magnetic Weyl semimetals, Weyl points related physics was observed in them so far. In this work, we find a Weyl semimetal phase in half metallic ferromagnet $Co_3Sn_2S_2$ with Weyl points only 60 meV away from the Fermi level, which derive from nodal lines that are gapped by spin-orbit coupling. Therefore, the Weyl-related physics should be easy to detected by both surface ARPES and bulk transport measurements. Due to the Berry curvature deriving from the gapped nodal lines and Weyl points, its anomalous Hall conductivity can reach up to 1200 S/cm. Substituting S by Se, $Co_3Sn_2Se_2$ shows very similar property. Moreover, since $Co_3Sn_2S_2$ and $Co_3Sn_2Se_2$ are both easily grown quasi two-dimensional compounds, they provide an ideal platform for the study of magnetic Weyl physics and its future application in topological material based spintronic devices.

MA 36.12 Wed 18:00 EB 407

Core-Shell Nanowires of 3D Topological Insulators — •Kevin Geishendorf, Tommi Tynell, Kornelius Nielsch, and Andy Thomas — Institute for Metallic Materials, IFW Dresden

Topological insulators (TI) are promising candidates for next generation electronic/spintronic devices. The gapless surface states (SS) in TI exhibit a very high mobility and strongly suppressed backscattering due to spin-momentum locking. However, to exploit those advantageous one has to decrease the finit bulk conductance present in most TI systems.

One approach to achieve this reduction is to utilize band bending which occurs at the interface between two materials with different Fermi levels. The band bending leads to a charge depletion/ or accumulation near the interface. It therefore provides a tool to shift the fermi energy closer to the Dirac point.

In this work we have grown core-shell nanowires using Vapor-Liquid-Solid (VLS) growth and Atomic Layer Deposition (ALD). As core material Bi_2Se_3 and as shell materials Al_2O_3 and Sb_2Te_3 were employed. The uniformity, crystallinity and composition of those core-shell nanowire was investigated using TEM, nanodiffraction and EDX. Furthermore, devices for transport experiments were built using optical lithography and lift-off techniques. With those devices cryogenic magneto transport measurements have been performed revealing quantum interference effects such as weak-antilocalization and universal conductance fluctuations.

MA 37: Multiferroic Oxide Thin Films and Heterostructures II (joint session KFM/TT/MA)

Organizers: César Magén - University of Zaragoza, Aragón (Spain); Kathrin Dörr - Martin-Luther-Universität Halle-Wittenberg - Halle

Time: Wednesday 15:00–18:15 Location: EMH 225

Invited Talk MA 37.1 Wed 15:00 EMH 225

Merging Nonlinear Optics and Multiferroic Heterostructure Design — •Manfred Fiebig — Department of Materials, ETH Zurich, Vladimir-Prelog-Weg 4, 8093 Zurich, Switzerland

Despite the large variety of valuable tools that are at our disposals for characterizing oxide thin films, some of their functionalities remain invisible. Buried layers and their ordering and interactions are difficult to access. We show how optical second harmonic generation (SHG) allows us to detect such hidden properties. We show how the real-time dynamics of a domain patterns in multiferroic $BiFeO_3$ is tracked by SHG through a ferromagnetic metallic cover layer, thus identify the magnetoelectric domain coupling nondestructively during the poling process [1]. SHG furthermore resolves the domain-wall architecture in tetragonal ferroelectric thin films. In $PbZr_{0.2}Ti_{0.8}O_3$ films it quantifies the buried distribution of a- and c-domains and reveals that c-domain walls exhibit a mixed Ising-Néel-type transverse rotation of polarization across the wall [2]. Finally, by coupling a laser beam into the deposition chamber, SHG follows the evolution of the spontaneous polarization of complex multiferroic heterostructure in real time and with monolayer sensitivity throughout the entire deposition process. Such in-situ SHG allows us tailor heterostructures with an arbitrary sequence of ordered states which could become the key to whole new class of functional ferroelectric materials [3].

[1] M. Trassin *et al.*, Adv. Mater. **27**, 4871 (2015). **[2]** G. De Luca*et al.*, M. Trassin, Adv. Mater. **29**, 1605145 (2017). **[3]** G. De Luca*et al.*, Nature Comm. **8**, 1419 (2017)

MA 37.2 Wed 15:30 EMH 225

Real-time observation of polarization emergence in ultrathin ferroelectric heterostructures — •Gabriele De Luca[1], Nives Bonacic[1], Johanna Nordlander[1], Corinne Bouillet[2], Manfred Fiebig[1], and Morgan Trassin[1] — [1]Department of Materials, ETH Zurich, Vladimir-Prelog-Weg 4, 8093, Zurich, Switzerland — [2]Institut de Physique et Chimie des Matériaux de Strasbourg CNRS UMR 7504, 67034, Strasbourg, France

The integration of functional properties into oxide multilayer architectures demands for atomic precision. In-situ diagnostic tools guarantee high structural quality but are usually insensitive to the functionality targeted with the actual deposition. The conventional optimization process requires multiple samples and ex-situ analysis. Here, we take advantage of the non-invasive nature of optical probes and monitor the functionality during growth. Taking ferroelectricity as a representative case, we show that optical in-situ second harmonic generation (ISHG) analysis can be performed simultaneous to the pulsed-laser-deposition growth operation. We follow the evolution of the spontaneous polarization in real time and with monolayer resolution throughout the deposition process [1]. Such direct access allows validating the growth of oxide heterostructures with an arbitrary sequence of up- and down-polarized ferroelectric layers. This is only the first step in the implementation of ISHG as a growth diagnostic tool. The in-situ access to emerging properties enables an unprecedented degree of control that can promote the engineering of oxides functionalities to a completely new level.

[1] G. De Luca et al., Nat. Commun. 8, 1419 (2017)

MA 37.3 Wed 15:45 EMH 225

Controlling the effect of the depolarizing field in $BaTiO_3$-$SrTiO_3$ multilayers — •Nives Bonacic[1], Gabriele De Luca[1], Shovon Pal[1], Marco Campanini[2], Marta D. Rossell[2], Morgan Trassin[1], and Manfred Fiebig[1] — [1]ETH Zurich, Department of Materials — [2]EMPA, Switzerland

The demand for ever-smaller devices has been approaching the fundamental limits of ultrathin ferroelectric films. In the low-thickness regime, maintaining a large, stable and switchable ferroelectric polarization relies on the control of the strain state, thickness, interface termination and electrostatic conditions. Achieving a robust polarization or a controlled domain state remains, however, challenging. Imperfect charge screening at interfaces results in non-cancellation of internal fields that can in extreme case annihilate ferroelectricity. Taking ($BaTiO_3$-$SrRuO_3$) capacitor-like heterostructures as a model system, we directly access the polarization and the domain state during the film deposition using optical second harmonic generation [1]. We observe a previously elusive impact of the evolving electrostatic environment on the $BaTiO_3$ domain state simultaneously with the growth. The initial phase of the top-electrode deposition is accompanied by temporary enhancement of built-in fields in the ferroelectric layer resulting in 180° domain formation. We discuss ways to manipulate the depolarizing field and control the polarization during the growth as it presents a possible route towards a novel class of oxide-electronic devices. [1] G. De Luca et al., Nat. Commun. 1419 (2017).

MA 37.4 Wed 16:00 EMH 225

In-situ characterization of improper ferroelectricity in ultrathin multiferroic h-$YMnO_3$ films — •Johanna Nordlander[1], Marta D. Rossell[2], Rolf Erni[2], Manfred Fiebig[1], and Morgan Trassin[1] — [1]ETH, Zürich, Switzerland — [2]EMPA, Dübendorf, Switzerland

Improper ferroelectrics are materials whose ferroelectricity is driven by another, primary, order parameter. This type of ferroelectricity can lead to exotic properties that do not exist in standard ferroelectrics. In the case of bulk hexagonal manganites, the structural trimerization results in a topologically protected vortex domain structure. Due to their potential for extending existing technological applications with complex functional properties, there has been a revival of interest in hexagonal manganite thin films. Here we demonstrate the growth of highly oriented, epitaxial hexagonal $YMnO_3$ thin films using pulsed laser deposition. We use in-situ optical second harmonic generation (SHG) to non-invasively probe, in real time during and after the deposition process, the ferroic state of the films in the ultrathin regime. With the complementary use of reflection high-energy electron diffraction (RHEED), the emerging polarization of $YMnO_3$ is resolved with monolayer precision. The characteristic improper ferroelectric domain pattern in the ultrathin $YMnO_3$ films is investigated using scanning transmission electron microscopy. This work provides new insights in the early stage of improper ferroelectricity and domain state in hexagonal $YMnO_3$ thin films - especially the drastic influence of epitaxial strain and reduced dimensions on the ferroelectric Curie temperature.

MA 37.5 Wed 16:15 EMH 225

Multiferroic and magnetoelectric nanocomposites for data processing — •Wolfgang Kleemann — Physics Department, University Duisburg-Esssen, 47048 Duisburg, Germany

Switching of magnetism with electric fields and magnetic control of electric polarization are challenging tasks for multiferroic and magnetoelectric materials. Various composite realizations appear most promising for data processing applications: (1) We propose 2-2 nanocomposites based on magnetoelectric (ME) chromia (111) films (Cr2O3), which allow electric switching of the magnetization of epitaxially grown ultrathin ferromagnetic Co/Pt/Co trilayers via interfacial exchange bias. Random access memory (MERAM) and logic cell MEXOR have been approved [1]. (2) Regular 2-1 composites of magnetostrictive cobalt ferrite (CoFe2O4) nanopillars are PLD-grown in a piezoelectric film of barium titanate (BaTiO3). In a transverse magnetic field they exert a staggered shear stress-induced surface polarization pattern in the BaTiO3 environment [2]. Possible data storage applications will be discussed. (3) Ceramic 0-3 composites of antiferromagnetic-ferroelectric Bi(Fe,Co)O3 nanoclusters embedded in K0.5Bi0.5TiO3 reveal giant linear magneto-electric response via bilinear piezo-magneto-electric coupling, $M = \alpha E$ with α = 10-5 s/m [3]. They are candidates for future electrically addressable nanodot mass memory devices. [1] US Pat. 7,719,883 B2 (2010). [2] Nature Comm. 4, 2051 (2013). [3] Adv. Funct. Mater. 26, 2111 (2016).

15 min. break

MA 37.6 Wed 17:00 EMH 225

Local observables in inhomogenous systems — •Raffaele Resta[1] and Antimo Marrazzo[2] — [1]IOM-CNR, Trieste, Italy —

[2]THEOS, EPF Lausanne, Switzerland

When addressing inhomogenous systems (e.g. heterostructures) a key issue is which physical properties do (or do not) admit a local expression. It is known since long time that spin magnetization is indeed local, and that the density of spin magnetization is well defined quantity. It is also known (since the early 1990s) that instead polarization density is an ill defined concept. Bulk electric polarization P is a Berry phase of the electronic wavefunction: as such it does not admit any local representation. In analogy with P, orbital magnetization is a geometrical property of the electronic ground state; but at variance with P, it also admits a local representation with a well defined density in coordinate space [1,2]. Here we address one further property: the insulating/metallic character of a region in an inhomogeneous system. A well known tool to investigate this property is the local density of states, but it is not a ground-state property. According to Kohn (1964) the insulating/metallic character of a material stems from a different organization of the electrons in their ground state. We define a local "marker" which probes such organization, and we validate it by means of computer simulations.

[1] R. Bianco and R. Resta, Phys. Rev. Lett. 110, 087202 (2013)
[2] A. Marrazzo and R. Resta, Phys. Rev. Lett. 116, 137201 (2016)

MA 37.7 Wed 17:15 EMH 225

Magnetoelectric coupling and multicaloric effects in $SrMnO_3$ — Alexander Edström and •Claude Ederer — Materials Theory, ETH Zürich, Switzerland

$SrMnO_3$ is a G-type antiferromagnet where ferroelectricity can be induced by epitaxial strain or Ba-substitution. Furthermore, a transition to ferromagnetic order has been predicted under large tensile strain [1], and the two ordering temperatures can in principle be tuned to coincide by varying both strain and composition. $SrMnO_3$ is thus a very rare example of a multiferroic with proper ferroelectric and magnetic order and similar ordering temperatures.

We use first principles electronic structure calculations in combination with first-principles-derived effective model Hamiltonians to obtain the temperature and strain-dependent ferroelectric/magnetic phase diagram of $SrMnO_3$. We then explore coupling effects between the polar and magnetic order. A particular focus thereby are possible multi-caloric effects, i.e., adiabatic temperature changes induced by applied electric and/or magnetic fields, that are very promising for future solid state cooling devices [2].

[1] J. H. Lee and K. M. Rabe, Phys. Rev. Lett. 104, 207204 (2010).
[2] X. Moya, S. Kar-Narayan, and N. D. Mathur, Nature Mater. 13, 439 (2014).

MA 37.8 Wed 17:30 EMH 225

Octahedral tilting, phonons and Goldstone modes in 111-strained perovskites — Magnus Moreau[1], Astrid Marthinsen[1], Sinead Majella Griffin[2], Tor Grande[1], Thomas Tybell[1], and •Sverre Magnus Selbach[1] — [1]NTNU Norwegian University of Science and Technology, Trondheim, Norway — [2]Lawrence Berkeley National Laboratory, Berkeley, California, USA

Epitaxial strain has been extensively explored to enhance existing and enable new functional properties in perovskites oxide thin films, with the majority of the work done on 001-oriented films. Recent advances in film growth has made other epitaxial orientations possible, and particularly 111-oriented films show interesting properties because of the different symmetry and chemical bonding at the terminating (111) facet. We use density functional theory (DFT) calculations to study the different response to 111- and 001-strain of the octahedral tilt system and the crystal field splitting of perovskite oxides. Unlike 001-strain, 111-strain is parallel to the edges of the oxygen octahedra, and tensile 111-strain can emulate negative hydrostatic pressure, which is not easily realised experimentally for bulk materials. General trends for how 111-strain affects polar and rotational modes are outlined based on calculations of twenty common perovskites. Furthermore, we show that in SrMnO3 compressive 111-strain give rise to Goldstone-like phonon modes with a Mexican hat-shaped energy surface, while large tensile strain can induce polar Goldstone modes. The chemical and structural requirements for engineering structural Goldstone modes in 111-strained perovskites are finally discussed.

MA 37.9 Wed 17:45 EMH 225

Voltage controlled magnetization dynamics in nanostructured multiferroic multilayer systems — •Alexander F. Schäffer and Jamal Berakdar — Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany

We investigate the control of magnetization dynamics by applying localized voltages in the framework of nanostructured multiferroic heterostructures. Manipulations of the magnetic anisotropy are spatially controlled by nanostructuring. This combination is utilized as a toolbox to excite or manipulate magnetic systems in order to manipulate multiple magnetic phenomena, such as the magnon dispersion, local spin current sources, or local non-collinear magnetic textures. Full-fledged numerical calculations for realistic systems along with basic analytical models will be shown in order to point towards opportunities for further experimental investigations and applications.

MA 37.10 Wed 18:00 EMH 225

Electronic and magnetic properties of $BaFeO_3$-Pt(111) in a quasicrystalline approximant structure — •Waheed A. Adeagbo, Igor V. Maznichenko, Hichem Ben-Hamed, Ingrid Mertig, and Wolfram Hergert — Institute of Physics, Martin Luther University Halle-Wittenberg, Germany

The first reported formation of an oxidic quasicrystal (OQC) $BaTiO_3$ (BTO) on Pt(111) has led to finding of other quasicrystalline (QC) perovskites like $SrTiO_3$ on the same substrate. Since these are non-magnetic, it is interesting to investigate the properties of magnetic perovskites in corresponding approximant structures. $BaFeO_3$ (BFO) has a very good lattice match with Pt(111) and also a robust magnetic properties which could add new interesting features to the QC systems. In this work we have carried out first principles study on the periodic BFO bulk crystals properties in the cubic (c-BFO) and the hexagonal ($6h$-BFO) phases. The derived OQC thin film which exhibits strong similarities to the BTO-derived OQC with respect to the local tiling geometry of Kepler's approximant was also studied both in the free standing and in the supported phase on Pt(111) surface. Our results shows that the anti-ferromagnetic $6h$-BFO bulk phase is preferable ground state to c-BFO phase. Like in BTO-OQC approximant, the BFO also shows all four Fe atoms surrounded by three O atoms with the FeO_3 units separated by Barium atoms with the total stoichiometry $Ba_5Fe_4O_{10}$. Since the exact oxidation states of the Fe and the role of O vacancy in the stabilization is unknown for these systems, the results of these will be presented together with the magnetic contribution.

MA 38: Theory of strongly correlated systems

Time: Thursday 9:30–13:15 Location: H 0110

Topical Talk MA 38.1 Thu 9:30 H 0110

RKKY-induced Kondo breakdown near a magnetic quantum phase transiton — •Johann Kroha — Universität Bonn, Germany — CCM, Zhejiang University, Hangzhou, China

The fate of the fermionic quasiparticles near a magnetic quantum phase transition (QPT) in heavy-fermion (HF) compounds has been controversial for many years. It is generally believed that this Kondo destruction is driven by the critical fluctuations near the QPT. A novel renormalization group treatment of the quantum interference of Kondo and RKKY couplings shows, however, that the HF quasiparticles can be destroyed by the RKKY interaction even without critical fluctuations [1], with far reaching consequences for the QPT scenario: The lattice Kondo temperature, $T_K^*(y)$, is suppressed in a universal way by the dimensionless RKKY coupling y, with a discontinuous breakdown at a critical value $y = y_c$. This agrees quantitatively with STM spectroscopy on continuously tunable two-impurity Kondo systems [2]. We analyze in detail most recent time-resolved THz reflectometry experiments on the HF compound $CeCu_{6-x}Au_x$ across the QPT at x=0.1 [3]. The theoretical as well as the experimental findings point to a new quantum critical scenario, realized in $CeCu_{6-x}Au_x$, where the HF quasiparticles disintegrate in that their spectral weight vanishes continuously, but $T_K^*(y)$ remains finite. This is consistent with ω/T scaling as an indicator for critical Kondo destruction.

[1] A. Nejati, K. Ballmann, J. Kroha, PRL **118**, 117204 (2017)
[2] J. Bork, Y.-H. Zhang, L. Diekhöhner *et al.*, Nature Phys. **7**, 901 (2011)
[3] Ch. Wetli, J. Kroha, K. Kliemt *et al.*, arXiv:1703.04443

MA 38.2 Thu 10:00 H 0110

Dynamics of the magnetic moments in correlated metals: The case of Fe and Ni from ambient to Earth's core conditions — Andreas Hausoel[1], Micheal Karolak[1], Giorgio Sangiovanni[1], Ersoy Sasioglu[2], Alexander Lichtenstein[3], Andrey Katanin[4], Kasten Held[5], and •Alessandro Toschi[5] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, 97074, Germany — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425, Germany — [3]Institut für Theoretische Physik, Universität Hamburg, 20355, Germany — [4]Institute of Metal Physics, 620990 Ekaterinburg, Russia — [5]Institute of Solid State Physics, TU Wien, 1040 Vienna, Austria

The formation of localized magnetic moments and their dynamical screening represents one of the crucial ingredients for the physics of correlated metals. Their fingerprints appear, sometimes in different ways, in transport and spectroscopic experiments. As a relevant example, we present here our most recent ab-initio (DFT) + DMFT calculations [1] for two of the most common ferromagnetic elements: Fe and Ni, both at ambient and Earth's core conditions. The comparison of the results inspires the interesting hypothesis of a more important role played by Ni for the generation of the Earth's magnetic field, than hitherto postulated.

[1] A. Hausoel, M. Karolak, E. Sasioglu, A. Lichtenstein, K. Held, A.A. Katanin, A. Toschi, and G. Sangiovanni, Nature Communications **8**, 16062 (2017).

MA 38.3 Thu 10:15 H 0110

Time-reversal origin of anisotropies for non-Kramers magnetic states — •Bruno Tomasello and Tim Ziman — Institut Laue-Langevin, CS 20156, Cedex 9, 38042 Grenoble, France

Magnetic anisotropies of rare-earth ions characterise unconventional phases in many condensed matter systems. The theoretical effort for describing such phases typically begins by "adjusting" suitable *pseudo-spin* Hamiltonians which can account for complex exotic behaviours and yet involve simple enough mathematics. A case per se are *non-Kramers* bound-ions whose spectra features a *neat* separation of the lowest energy states from the higher ones. In this talk, focusing on non-Kramers magnetic ions, I will discuss the relationship between *time-reversal* properties and the origin of axial anisotropies. Emphasis will be given to identifying the *microscopic* mechanisms of interest from established theoretical frameworks. The analysis will be contextualised in the perspectives of recent dispersive signatures in the low-temperature neutron-scattering experiments on powders of the *garnet* $Tb_3Ga_5O_{12}$, which is well known for detection of *phonon Hall* physics.

MA 38.4 Thu 10:30 H 0110

Electronic entropy in finite-temperature Green's-function calculations — •Ilja Turek[1,2], Josef Kudrnovsky[3], and Vaclav Drchal[3] — [1]Institute of Physics of Materials, Czech Acad. Sci., Brno, Czech Rep. — [2]Charles University, Faculty of Mathematics and Physics, Prague, Czech Rep. — [3]Institute of Physics, Czech Acad. Sci., Prague, Czech Rep.

Reliable evaluation of thermodynamic potentials of metallic materials and itinerant magnets at finite temperatures (free energy, grand-canonical potential) requires investigation of systems with perturbed translation invariance. For this purpose, Green's-function techniques are often applied, which use a complex energy variable and integrations over contours in the complex plane. However, for quantities related to the electronic entropy, the branch cut of the complex logarithmic function prevents standard deformations of the integration paths. We have derived and numerically implemented an alternative expression for the electronic entropy, which is not affected by the multi-valued nature of the complex logarithm. In this contribution, the developed theoretical formalism will be presented and its efficiency and accuracy in selected cases (on model and *ab initio* levels) will be discussed.

MA 38.5 Thu 10:45 H 0110

Asymmetry of the density of states and magnetic exchange interactions in Hund's metals — •Andrey Katanin[1,2], Alexander Belozerov[1,2], and Vladimir Anisimov[1,2] — [1]Institute of Metal Physics, Ekaterinburg, Russia — [2]Ural Federal University, Ekaterinburg, Russia

We discuss the effect of the asymmetry of the density of states on a possibility of Hund's metal behaviour and the way of calculation of the respective exchange interactions between frozen-spin states, corresponding to local moments. We find that quasiparticle damping and the formation of local magnetic moments due to Hund's exchange interaction are enhanced by asymmetry of the density of states; the properties of Hund's metal are mainly observed close to half filling, on the same side of half filling as the maximum of the density of states, and become stronger with increasing asymmetry. We also suggest the way to calculate the magnetic exchange interaction of Hund's metals within the supercell DMFT approach. We discuss implication of the obtained results to alpha-iron, for which ab initio calculations show a possibility of realization of Hund's metal behavior, and obtain the respective momentum- and temperature dependences of the magnetic susceptibilities and magnetic exchange interaction in this substance.

15 minutes break

MA 38.6 Thu 11:15 H 0110

Source-free exchange-correlation magnetic fields in density functional theory — •John Kay Dewhurst, E. K. U. Gross, Antonio Sanna, and Sangeeta Sharma — Max Planck Inst. of micro structure physics, Halle, Germany

Spin-dependent exchange-correlation energy functionals in use today depend on the charge density and the magnetization density: $E_{\rm xc}[\rho, \mathbf{m}]$. However, it is also correct to define the functional in terms of the curl of $\mathbf{m}$ for physical external fields: $E_{\rm xc}[\rho, \nabla \times \mathbf{m}]$. The exchange-correlation magnetic field, $\mathbf{B}_{\rm xc}$, then becomes source-free. We study this variation of the theory by uniquely removing the source term from local and generalized gradient approximations to the functional. By doing so, the total Kohn-Sham moments are improved for a wide range of materials for both functionals. Significantly, the moments for the pnictides are now in good agreement with experiment. This source-free method is simple to implement in all existing density functional theory codes.

MA 38.7 Thu 11:30 H 0110

Electronic structure and antiferromagnetism in a three-orbital model for iron pnictides. — •Sayandip Ghosh — Institute for Theoretical Physics, TU Dresden

The iron pnictides are the new class of high T_c superconductors after cuprates. They exhibit a rich temperature-doping phase diagram in which the parent compounds go through a structural transition and a magnetic phase transition to stripe antiferromagnetic (AFM) state. The electronic structure from first-principle techniques and ARPES experiments reveal two nearly circular hole pockets and two elliptical electron pockets. The magnetic excitations in the magnetic state examined by inelastic neutron scattering measurements yield well defined spin wave excitations with a maximum at the ferromagnetic zone boundary. Towards understanding the electronic and magnetic properties, we propose and investigate a three-orbital itinerant-electron model and show that essential features of electronic structure and magnetism can be understood in this model. We also demonstrate how the effective spin couplings are generated from particle-hole propagator explaining microscopic origin of ferromagnetic spin coupling along b direction required to understand spin wave dispersion.

MA 38.8 Thu 11:45 H 0110

Theory of noncollinear interactions beyond Heisenberg exchange: Applications to bcc Fe — •Attila Szilva[1], Danny Thonig[1], Pavel Bessarab[2], Yaroslav Kvashnin[1], Debora Rodrigues[3], Ramon Cardias[1], Manuel Pereiro[1], Lars Nordström[1], Anders Bergman[1], Angela Klautau[3], and Olle Eriksson[1] — [1]Department of Physics and Astronomy, Division of Materials Theory, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [2]Science Institute of the University of Iceland, 107 Reykjavik, Iceland and Department of Nanophotonics and Metamaterials, ITMO University, 197101 St. Petersburg, Russia — [3]Faculdade de Física, Universidade Federal do Pará, Belém, 66075-110, Brazil

We show for a simple noncollinear configuration of the atomistic spins (in particular, where one spin is rotated by a finite angle in a ferromagnetic background) that the pairwise energy variation computed in terms of multiple-scattering formalism cannot be fully mapped onto a bilinear Heisenberg spin model even in the absence of spin-orbit coupling. The non-Heisenberg terms induced by the spin-polarized host appear in leading orders in the expansion of the infinitesimal angle variations. However, an Eg-T2g symmetry analysis based on the orbital decomposition of the exchange parameters in bcc Fe leads to the conclusion that the nearest-neighbor exchange parameters related to the T2g orbitals are essentially Heisenberg-like: they do not depend on the spin configuration, and can, in this case, be mapped onto a Heisenberg spin model even in extreme noncollinear cases.

DOI: 10.1103/PhysRevB.96.144413

MA 38.9 Thu 12:00 H 0110

Calculation of micromagnetic parameters and spin-wave stiffness using the SPR-KKR method — •Sergiy Mankovsky[1], Ondrej Šipr[2], Sebastian Wimmer[1], Svitlana Polesya[1], and Hubert Ebert[1] — [1]Dept. Chemistry, LMU Munich, D-81377 Munich, Germany — [2]Institute of Physics ASCR v. v. i., CZ-162 53 Prague, Czech Republic

We present an approach for the calculation of the micromagnetic exchange stiffness ($A_{\alpha\beta}$) as well as the closely related spin-wave stiffness, and Dzyaloshinskii-Moriya ($D_{\alpha\beta}$) tensors, based on the fully relativistic multiple scattering Korringa-Kohn-Rostoker (KKR) formalism. Results for ordered systems and for disordered alloys are compared with experimental results as well as with results based on the parameters of the relativistically extended Heisenberg model, that were calculated within the same ab-initio framework. In general a good agreement between the micromagnetic parameters calculated directly and those derived from other parameters, as well as from experiment, is found.

MA 38.10 Thu 12:15 H 0110

Comparison of different approaches to ab-initio calculations of the spin wave stiffness — •Ondřej Šipr[1], Sergey Mankovsky[2], and Hubert Ebert[2] — [1]Institute of Physics, Czech Acadademy of Sciences, Praha, Czech Republic — [2]Ludwig-Maximilians-Universität München, Germany

The spin waves stiffness constant D is one of the basic quantities characterizing magnetism in solids. Ab-initio calculations of spin wave stiffness reported in the literature have been performed within the scalar relativistic approximation. Usually D is evaluated either (i) in real space as a weighted sum of exchange coupling constants or (ii) in reciprocal space by fitting the spin-wave dispersion in the long-wave limit to a parabola. Even though both approaches look conceptually simple, theoretical values of D obtained for Fe and Ni by different groups show considerable spread of 50–100 %. We present results for the spin waves stiffness constant D of Fe, Ni, and permalloy $Fe_{0.2}Ni_{0.8}$ obtained by explicit summation of weighted exchange coupling constants as well as by fitting the spin-wave dispersion. We demonstrate that both procedures yield similar values when properly converged and we discuss which issues are crucial in this respect (especially concerning the summation of weighted exchange coupling constants and its extrapolation to the limit of zero damping). We inspect to what extent the energies of spin spirals can be described within the magnetic force theorem. In addition, we show how the spin waves stiffness changes if spin-orbit coupling is taken into account.

MA 38.11 Thu 12:30 H 0110

First-principles study of the magnetic and electronic properties of cubic GdCu compound — •Vikas Kashid[1], Ersoy Şaşioğlu[2], Gustav Bihlmayer[1], and Stefan Blügel[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum, Jülich and JARA, Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany

We investigate the structural and magnetic properties of bulk GdCu (CsCl type) using spin density functional theory, where highly localized $4f$ orbitals are treated within LDA+U and GGA+U methods. The calculated magnetic ground state of GdCu exhibits a C-type antiferromagnetic configuration representing a propagation vector $\mathbf{Q} = (\pi, \pi, 0)$. The estimated Néel temperature of the cubic GdCu using GGA+U and LDA+U density functionals is 161 and 115 K, respectively within the mean field approximation (MFA). In particular, the theoretical understanding of Gd and Cu core level shift observed in photoemission spectroscopic experiments are investigated in detail. We find that, the shift of Gd-$4f$ states in GdCu with respect to bulk Gd, is due to the extra correlation (Hubbard U) of $4f$ electrons in the GdCu lattice. The core level shift in GdCu is studied using the Random Phase Approximation (RPA) and found sensitive to the choice of lattice parameters and the exchange functional.

MA 38.12 Thu 12:45 H 0110

Anatomy of the magnetic anisotropy energy mediated by tight-binding Rashba electrons — Gaurav Chaudhary[1], •Manuel dos Santos Dias[2], Allan H. MacDonald[1], and Samir Lounis[2] — [1]Department of Physics, The University of Texas at Austin, Austin, Texas 78712, USA — [2]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Perpendicular magnetic anisotropy (PMA) is one of many properties that can arise from the interface between a ferromagnetic layer and a heavy-metal one. The free-electron Rashba model, often used to describe the properties of such interfaces, has been shown not to support PMA [1]. We reprise the tight-binding model of Ref. [1], describing spin-orbit-coupled electrons exchange-coupled to a background ferromagnetic order. The band energy differences approach is compared with a new description based on the static uniform spin susceptibility of the electronic system, and with a proposal of Antropov based on the spin-orbit energy [2]. We investigate not only their compatibility but also what physical insights can be gained from each of them.

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

[1] K.-W. Kim *et al.*, Phys. Rev. B **94**, 184402 (2016)
[2] V. Antropov *et al.*, Solid State Commun. **194**, 35–38 (2014)

MA 38.13 Thu 13:00 H 0110

Calculated Curie temperatures of metallic ferromagnets — •Roman Kováčik, Phivos Mavropoulos, Konstantin Tillmanns, and Stefan Blügel — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

We analyze the predictive power of the local density approximation, generalized gradient approximation, and disordered local moment method in connection with the classical Heisenberg model to determine the critical temperature of the magnetic phase transition for a large set (about 100) of bulk materials from the Heusler family alloys. To obtain the electronic structure we employ the *ab initio* Korringa-Kohn-Rostoker Green function method [1] where the exchange parameters are calculated by the method of infinitesimal rotations [2]. The magnetization curve as a function of temperature is simulated by the Monte Carlo method. The fourth-order cumulant is used to determine the critical temperature while its convergence is ensured with respect to the exchange parameters cut-off distance and the supercell size of the Monte Carlo simulation. Finally, we evaluate the effective magnetic moment and analyze our results in comparison with the experimental data. Support from JARA-HPC (jara0051) is gratefully acknowledged. [1] H. Ebert *et al.*, Rep. Prog. Phys. 74, 096501 (2011), also see: www.kkr-gf.org. [2] A. I. Liechtenstein *et al.*, J. Magn. Magn. Mater. 67, 65 (1987).

MA 39: Micro- and nanostructured magnetic materials

Time: Thursday 9:30–11:15 Location: H 0112

MA 39.1 Thu 9:30 H 0112

Annealing-time and annealing-temperature dependencies of the size of Ni-Mn-In shell-ferromagnetic nano-precipitates by Scherrer analysis — •Lars Dincklake[1], Franziska Scheibel[1], Asli Cakir[2], Michael Farle[1], and Mehmet Acet[1] — [1]Faculty of Physics, University of Duisburg-Essen, 47057 Duisburg, Germany — [2]Mugla Sitki Kocman University, 48000 Mugla, Turkey

Shell-ferromagnetic effects are observed in Ni-Mn-based off-stoichiometric Heuslers decomposed into ferromagnetic precipitates embedded in an antiferromagnetic matrix when the surface-to-volume ratio of the precipitates are sufficiently large. However, since the size of the precipitates have until now not been determined, it is not known which ratios are involved. Here we carry out a Scherrer analysis on decomposed specimens to determine the precipitate-size as a function of decomposition temperature and time.

MA 39.2 Thu 9:45 H 0112

Magnetic Behavior of EuO Tubes Prepared via a Topotactic Nanostructure Transition — •Severin Selzer[1], Bastian Trepka[1], Philipp Erler[1], Tom Kollek[1], Klaus Boldt[1], Mikhail Fonin[1], Daniel Wolf[2], Axel Lubk[2], Sebastian Polarz[1], and Ulrich Nowak[1] — [1]Universität Konstanz, Universitätstraße 10, D-78457 Konstanz — [2]IFW Dresden e.V., Helmholtzstraße 20, D-01069 Dresden

Being one of the few native ferromagnetic semiconductors, europium(II)oxide offers a great potential for the realization of spintronic devices. However, due to its reducing nature no reliable routes for EuO nanoparticle synthesis can be established. Instead of targeting a direct synthesis, the two steps – structure control and chemical transformation – are separated. The generation of a transitional, hybrid nanophase is followed by its conversion into EuO under full conservation of all morphological features.

Via this route EuO nanoparticles with tubular character and lamellar structure are now accessible. This special structure has a large impact on the key magnetic properties of these nanotubes. For a single layer of these tubes magnetic vortex or onion states have been found. Stacked to a tube, these layers couple antiferromagnetically in order to reduce their stray-fields. Owing to thermally activated transitions between these states an unexpected temperature dependence emerges (Trepka et al., Adv. Mater. 2017, 1703612).

Financial support by the DFG within SFB1214 is gratefully acknowledged.

MA 39.3 Thu 10:00 H 0112

Investigation of magnetization reversal processes in bent nanofibers — •Tomasz Blachowicz[1] and Andrea Ehrmann[2] — [1]Silesian University of Technology, Institute of Physics - Center for Science and Education, 44-100 Gliwice, Poland — [2]Bielefeld University of Applied Sciences, Faculty of Engineering and Mathematics, 33619 Bielefeld, Germany

Biologically inspired computer hardware, giving up the classical von Neumann architecture with the strict separation of memory and processor, could be based on artificial ferromagnetic nanofiber networks with additional functionalities. As a first step to understand the magnetic processes in such networks, single nanofibers with varying cross-sections and bending radii were investigated by micromagnetic simulations under different angles with respect to the external magnetic field. Due to the strong shape anisotropy and proposed spatial dimensions, all magnetization reversal processes in these nanofibers took place via domain wall processes. Coercive fields and detailed reversal processes, however, significantly depended on the geometric parameters of the fibers. Variation of cross-sections, bending radii and angles between fiber and magnetic field thus resulted in a broad spectrum of possible magnetization reversal processes in magnetic nanofibers, giving rise to diverse scenarios for fiber-based information storage and processing.

[1] Tomasz Blachowicz, Andrea Ehrmann: Magnetization reversal in bent nanofibers of different cross-sections, arXiv:1711.09370

MA 39.4 Thu 10:15 H 0112

FORC based interaction strength investigations in permalloy micro arrays — •Felix Gross, Sven Erik Ilse, Joachim Gräfe, and Eberhard Goering — Max-Planck-Institut für Intelligente Systeme, 70569 Stuttgart

First-order reversal-curves (FORCs) are a powerful tool to distinguish between microscopic interaction and coercivity contributions. However, most real systems usually violate Mayergoyz' congruency property which has to be fulfilled to easily interpret a FORC diagram. Investigating systems which violate Mayergoyz' criteria gives new fundamental insight into the FORC method. To build such a well-defined system, permalloy micro arrays of alternating width have been designed. By varying width and spacing, we are able to manipulate coercivities and interaction strength. Using a NanoMOKE3[1] we directly measure the low field spatially resolved switching field distribution, which shows binary distributed coercivities around 1 and 3 Oe. Surprisingly, an unexpected positive-negative peak pair appears at negative interaction fields in the FORC density. We could reveal that the two peaks are caused by interaction of high and low coercivity components. More precisely, by the interaction field which causes the small coercivity component to flip at different fields in parallel or antiparallel configuration. From the intensities of the peaks for different spacings, we can conclude, that turning off the interaction leads to fulfilled Mayergoyz' criteria again.

[1] J.Gräfe, Rev Sci Instrum, 85(2), 023901; 2014.

MA 39.5 Thu 10:30 H 0112

Nanoscale control of geometrical frustration in a dipolar trident lattice — Alan Farhan[1], •Charlotte Petersen[2,3], Scott Dhuey[1], Luca Anghinolfi[4], Qi Hang Qin[2], Michael Saccone[5], Sven Velten[1,6], Clemens Wuth[1,7], Sebastian Gliga[8], Paula Mellado[9], Mikko Alava[2], Andreas Scholl[1], and Sebastiaan van Dijken[2] — [1]Lawrence Berkeley National Laboratory, Berkeley, CA, USA. — [2]Aalto University, Finland. — [3]Universität Innsbruck, Austria — [4]Università di Genova, Italy. — [5]University of California, Santa Cruz, CA, USA. — [6]Universität Hamburg, Germany. — [7]Daegu Gyeongbuk Institute of Science and Technology, Hyeonpungmyeon, Dalseong-gun, Daegu, Republic of Korea. — [8]University of Glasgow, UK. — [9]Adolfo Ibáñez University, Diagonal Las Torres, Peñalolén, Santiago, Chile.

Artificial spin ice consists of interacting magnetic subunits arranged on a two dimensional lattice. A key feature is the ability to precisely control the geometry, and so manufacture highly frustrated systems that are hindered to minimize their local interactions by lattice constraints. We present a new lattice geometry where the balance of competing interactions between nearest-neighbour moments can be directly controlled [1]. This allows for tuning of the geometrical frustration. By varying the lattice parameters, we observe that the system either accesses a long-range ordered ground state, or under the same conditions, remains in a disordered state with short-range correlations.

[1] A. Farhan et. al., Nature Communications 8, 995 (2017).

MA 39.6 Thu 10:45 H 0112

Two dimensional transport of superparamagnetic beads in periodic artificial magnetic stray field landscapes with inplane magnetization — •Jendrik Gördes[1], Dennis Holzinger[1], Johannes Loehr[2], Daniel de las Heras[3], Thomas M. Fischer[2], and Arno Ehresmann[1] — [1]Institute of Physics and Center for Interdisciplinary Nanostructure Science and Technology (CINSaT), University of Kassel, D-34132 Kassel — [2]Experimental Physics, Universität Bayreuth, D-95440 Bayreuth — [3]Theoretical Physics, Universität Bayreuth, D-95440 Bayreuth

The transport of superparamagnetic beads on top of periodic magnetic patterns is of particular interest for Lab-on-a-chip (LOC) devices, which offer promising applications in biomedicine [1]. Directed transport is achieved by modulation of the magnetic potential energy landscape by superposing a time dependent external magnetic field loop to the internal magnetic field of the pattern. As a result, remotely controlled two dimensional movement is obtained which is topologically robust against perturbations. Magnetic domain patterns of different symmetries were fabricated by lithography and ion bombardment induced magnetic patterning (IBMP). Characterization was done by longitudinal magneto-optical Kerr magnetometry (L-MOKE) and magnetic force microscopy (MFM). Investigations of the transport behavior of superparamagnetic beads above these patterns were carried out by tracking and image analysis techniques.

[1] D. Holzinger, I. Koch, S. Burgard, and A. Ehresmann, ACS Nano 9, 7323-7331 (2015)

MA 39.7 Thu 11:00 H 0112

Magnetic nanostructures in metastable fcc Fe thin films on Cu(100) and Si(100) — •Jonas Gloss[1], Michal Horký[2], Michal Andrýsek[3], Viola Křižáková[3], Lukáš Flajšman[2], Michael Schmid[1], Michal Urbánek[2,3], and Peter Varga[1,2] — [1]Inst. of Appl. Phys., TU Wien, AT — [2]Central EU Inst. of Tech., Brno University of Technology (BUT), CZ — [3]Inst. of Phys. Eng.,BUT, CZ

It has been shown that 5-10 ML thick Fe films grown on Cu(100) single crystal have an fcc structure and are nonmagnetic at room temperature [1]. Ion-beam irradiation of the fcc films causes a structural transformation from fcc to bcc, as well as a magnetic transformation from non- to ferromagnetic [2]. To remove the 10-ML thickness limit of fcc Fe we alloyed it with 22% of nickel to form a metastable fcc $Fe_{78}Ni_{22}$ [3].

To avoid the costly Cu single crystals, we also grew the films on H-terminated Si(100) with a Cu(100) buffer layer. The H-Si was prepared both in-situ by flashing and deposition of atomic H and ex-situ by etching in HF. The as-grown $Fe_{78}Ni_{22}$ films were corrugated yet metastable; we show they provide the opportunity to write magnetic nanostructures with a focused ion beam.

[1] A.Biedermann, et al., Phys. Rev. Lett. **87** (2001) 086103
[2] W. Rupp, et al., Appl. Phys. Lett. **93** (2008) 063102
[3] J. Gloss, et al., Appl. Phys. Lett. **103** (2013) 262405

MA 40: Focus Session: Spinorbitronics – from efficient charge/spin conversion based on spin-orbit coupling to chiral magnetic skyrmions I (joint session MA/TT)

This session will focus on the novel direction of spintronics, often called spin-orbitronics, that exploits the Spin-Orbit Coupling (SOC) in nonmagnetic materials instead of the exchange interaction to open fascinating new roads for basic research and new line of technologies. A first aim of this symposium will be to review both fundamental and theoretical recent advances made in using spin-orbit effects for generating or detecting spin-polarized currents either through bulk contributions e.g. the Spin Hall Effect or at interfaces through Rashba effects or topological surface states in topological insulators. Spin-orbit coupling can also be used in magnetic materials to create new types of topological objects such as chiral domain walls or magnetic skyrmions, that have generated a strong interest in the last couple of years. The second objective of this focused session will be to review the most recent significant results obtained to generate and characterize strong interfacial Dzyaloshinskii-Moriya Interactions (DMI). Beyond the stabilization of Néel domain walls in perpendicular magnetic layers with great promises for a new generation of race track memories, it has been recently that this chiral interaction plays a crucial role in the observation of magnetic skyrmions at room temperature. The goal will be here also to gather the key advances on the physics of magnetic skyrmions as well as on the potential applications and concept devices that shall leverage on their fascinating topological properties.

Organized by: Vincent Cros (Université Paris-Sud), Giovanni Finocchio (University of Messina)

Time: Thursday 9:30–12:30 Location: H 1012

Invited Talk MA 40.1 Thu 9:30 H 1012

Understanding Spin-Charge Conversion in Topological Insulators — •Aurelien Manchon — King Abdullah University of Science and Technology (KAUST), Physical Science and Engineering Division (PSE), Thuwal 23955-6900, Saudi Arabia

The interface between TI and 3d transition metal ferromagnets (3d-TM) represents a powerful platform for the realization of spin-charge conversion processes such as, but not limited to, spin pumping and spin-orbit torques. Uncovering the impact of 3d-TM overlayers on the surface states of TI and evaluating the resulting interfacial spin-momentum locking will undoubtedly open promising avenues for the efficient control of spin and charge currents mediated by spin-orbit coupling.

After a short review of the experimental results available, I will first discuss the spin-charge conversion processes expected from an ideal model. I will show that the very symmetry of the spin-orbit torques expected from topological surface states is quite different from the one observed experimentally. In a second part, based on recent density functional theory calculations, I will discuss the nature of interfacial orbital hybridization in 3d-TM adsorbed on Bi2Se3. Finally, based on these considerations I will present a minimal tight-binding model that allows us to inspect the transition between surface-dominated and bulk-dominated spin-orbit torque in 3d-TM/Bi2Se3 bilayers. This last model demonstrates that spin Hall effect arising from the bulk states of the topological insulator are unlikely to contribute to the last torque observed in experiments.

MA 40.2 Thu 10:00 H 1012

Impact of disorder on interfacial DMI for skyrmionics: intermixing and dusting — •Bernd Zimmermann[1], William Legrand[2], Nicolas Reyren[2], Vincent Cros[2], Stefan Blügel[1], and Albert Fert[2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, Germany — [2]Unité Mixte de Physique, CNRS, Thales, Univ. Paris-Sud, Université Paris-Saclay, Plaiseau, France

The spin-orbit (SOC) based Dzyaloshinskii-Moriya interaction (DMI) is of utmost importance for future nanotechnological devices, e.g. for the stabilization of small magnetic skyrmions in heterostructures such as magnetic multilayers. Additionally, the problematic role of disorder in such systems, e.g. leading to pinning of skyrmions, needs to be overcome making production processes tedious and expensive.

Here, we at first reveal from *ab initio* calculations for the important example of Co-Pt bilayers a surprisingly profound robustness of the DMI against interfacial intermixing. We incorporate disorder realistically by employing the coherent-potential approximation in combination with the Korringa-Kohn-Rostoker method. The robustness of DMI is a result of compensation, which turns out to follow simple arguments. We also explore the possibility to tune the DMI by dusting the interface with various impurities, including noble and transition metals, and elements with low and high SOC (bismuth and boron).

We acknowledge funding by a postdoc fellowship from DAAD, the EU's H2020 FET-open project "MAGicSky", and computing time on JURECA of JSC and JARA-HPC of RWTH Aachen University.

MA 40.3 Thu 10:15 H 1012

Control of the skyrmion Hall angle by combining spin-Hall effect, breathing mode and in-plane field — •Riccardo Tomasello[1], Anna Giordano[2], Roberto Zivieri[2], Vito Puliafito[3], Stefano Chiappini[4], Bruno Azzerboni[3], Mario Carpentieri[5], and Giovanni Finocchio[2] — [1]Dept. Engineering, Polo Scientifico e Didattico di Terni, University of Perugia, Terni, Italy — [2]Dept. Mathematical and Computer Sciences, Physical Sciences and Earth Sciences, University of Messina, Messina, Italy — [3]Dept. Engineering, University of Messina, Messina, Italy — [4]Istituto Nazionale di Geofisica e Vulcanologia, Roma, Italy — [5]Dept. Electrical and Information Engineering, Politecnico di Bari, Bari, Italy

The spin-Hall effect(SHE)-driven skyrmion motion is characterized by an in-plane angle, i.e. the skyrmion Hall angle (SHA)[1].

Here, we micromagnetically report, for the first time, the SHE-driven dynamics of a breathing skyrmion. In particular, we can excite the breathing mode by applying an ac perpendicular-polarized current[2] and we can control the SHA by an in-plane external field Hy. Our results show that the SHA depends on the SHE current only under the simultaneous presence of Hy and breathing mode. Our achievements can be important for understanding the origin of the SHA current dependence when the field-like torque comes from the SHE and the breathing mode is due to temperature and/or disordered parameters[3].

[1]G. Chen, Nat. Phys. 13, 112 (2017). [2]G. Finocchio et al., Appl. Phys. Lett. 107, 262401 (2015). [3]J.-V. Kim and M.-W. Yoo, Appl. Phys. Lett. 110, 132404 (2017).

MA 40.4 Thu 10:30 H 1012

Electric-field-induced and magneto-optic response properties of chiral magnetic solids — •Sebastian Wimmer, Sergiy Mankovsky, Svitlana Polesya, and Hubert Ebert — Dept. Chemie, LMU, München, Deutschland

Chiral magnetism and its manifestation in response properties such as Hall effects are one of the most attractive topics in current solid state science owing to their fascinating fundamentals as well as promising potential for application. This talk will report on the space-time symmetry restrictions on the tensor shapes of charge and spin conductivity, spin-orbit torque and (Rashba-)Edelstein effect and accompanying first-principles calculations of the respective response coefficients in Mn-based compounds experimentally known to exhibit large chirality-induced Hall effects. The numerical work has been performed using the spin-polarized relativistic Korringa-Kohn-Rostoker (SPR-KKR) multiple-scattering-based band structure method and Kubo's linear response formalism. The focus will be on chirality-driven or topological contributions arising due to a nonvanishing scalar spin chirality. Discussions will be based on computational studies of a spin texture smoothly varying between the collinear and noncollinear coplanar limits and manipulation of the spin-orbit coupling strength. Complementary results for orbital moments and current distributions as well as X-ray magnetic dichroism will be presented in addition.

30 minutes break

Invited Talk MA 40.5 Thu 11:15 H 1012

Interfacial spin-orbitronic: Rashba interfaces and topological insulators as efficient spin-charge current converters — •Juan-Carlos Rojas-Sanchez — Insitut Jean Lamour, Univ. Lorraine -CNRS, Nancy, France

New materials with large efficiency of spin-charge current interconversion are highly desirable to study new physical phenomena as well as for spintronics applications. The spin-orbit coupling (SOC) in the 2DEG states at Topological Insulator (TI) or Rashba Interfaces (RI) is predicted to be more efficient than their 3D counterparts for such interconversion. We have found the highest efficiency at room temperature using the topological insulator α-Sn [1]. The spin-to-charge current conversion in such 2D systems is called Inverse Edelstein Effect (IEE), or spin galvanic effect. I will show results of spin-to-charge conversion by spin pumping experiments and their analysis in term of inverse Edelstein Length in RI TI [1-3]. Experimental results based on ARPES and spin pumping indicate that direct contact of metallic ferromagnetic layer is detrimental for the surfaces states of topological insulators but we can keep the surfaces states of α-Sn using Ag spacer [1]. I will use the conversion parameter obtained at room temperature with α-Sn to demonstrate the very large advantage of the SOC effects in 2D interface states with respect to the Spin Hall Effect (SHE) of 3D metals and the resulting perspective for low power spintronic devices.

[1]J.-C. R-S et al. PRL 116, 096602 (2016). [2]J.-C. R-S et al. Nat. Comm 4, 2943 (2013). [3]E. Lesne, J.-C. R-S et al. Nat. Mat. 15, 1261 (2016).

MA 40.6 Thu 11:45 H 1012

Dynamical spin-orbitronic effects in exchange-bias bilayers from first-principles — •Filipe Souza Mendes Guimarães, Manuel dos Santos Dias, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

The interplay between charge and spin has been extensively studied in ferromagnetic systems. Recently, the focus has shifted to antiferromagnets, which are insensitive to external magnetic fields and offer much faster dynamics. When ferromagnets and antiferromagnets are coupled through the exchange bias, we can combine the best of both worlds [1]. For a deep understanding of such complex structures, a microscopic material-specific dynamical theory, such as the one we developed, is crucial [2,3]. In this work, we apply our theory to an idealized FePt/PtMn bilayer, to identify how the ferromagnet/antiferromagnet interface contributes to the dynamical magnetization and transport properties. We demonstrate how the resonances, reaching the THz range, may enhance the currents flowing through the system. The layer-resolved magnetic interactions and spin-orbit torques can also be used to understand switching processes of this type of heterostructures.

[1] S. Fukami *et al.*, Nature Materials **15**, 535–541 (2016)
[2] F. S. M. Guimarães *et al.*, Phys. Rev. B **92**, 220410(R) (2015)
[3] F. S. M. Guimarães *et al.*, Sci. Rep. **7**, 3686 (2017)

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

MA 40.7 Thu 12:00 H 1012

Determination of the Dzyaloshinskii-Moriya interaction in epitaxial asymmetric trilayers — •Fernando Ajejas[1], Adrian Gudin[1], Ruben Guerrero[1], Diane Chaves[2], Viola Křižáková[2], Jan Vogel[2], Stefania Pizzini[2], Paolo Perna[1], and Julio Camarero[1] — [1]IMDEA Nanociencia, Campus Universidad Autónoma de Madrid, Spain — [2]CNRS, Institut Néel, Université Grenoble Alpes, 38042 Grenoble, France

We will address the issue of domain wall velocity limitations in ultrathin magnetic films in symmetric and non-symmetric stacks. The DW wall speed is in general limited by the breakdown. This limitation is overcome in asymmetric trilayer systems in which Co is deposited on a heavy metal: in this case the Dzyaloshinskii-Moriya interaction (DMI) favours chiral Néel walls that are more stable against precession. It has been shown that in asymmetric thin layer systems the domain wall speed saturates above the Walker field, which is in general not the case for symmetric samples. Using magneto-optical Kerr magnetometry and microscopy, we measured domain wall velocities driven by magnetic field pulses in Pt/Co/Pt and Pt/Co/M (M=Al, Cu, Ir,) Typical Co thicknesses is 0.6 nm. The main result is that the saturation velocity of the DWs in the Pt/Co/M trilayers is strongly dependent on the nature of the top interface. We attribute this variation to the different contribution of the Co/M interfaces to the total DMI strength. The largest saturation velocities (typically 300m/s) are obtained for the samples covered by Al, Cu, or an oxyde, while much smaller velocities (typicaly 100m/s) are obtained for Ir or Ta top layers.

MA 40.8 Thu 12:15 H 1012

The spin-Hall stationarity conditions in the light of the second law of thermodynamics — •Jean-Eric Wegrowe[1], Rober Benda[1], Jean-Michel Dejardin[2], and Miguel Rubi[3] — [1]LSI, Ecole polytechnique, Palaiseau, France — [2]Laboratoire de Mathématique et Physique, Université de Perpignan, France — [3]Facultat de Fisica, Universitat de Barcelona, Spain

The determination of the stationary states for the bulk spin-Hall effect are discussed in the context of the two spin-channel model. It is shown that the usual stationarity condition (namely no explicit time-dependence) leads to an indeterminacy: different stationary states can equally be defined [1]. A first state S1 is characterized by a transverse pure spin current and no electric field while a second stationary state S2 is characterized by spin-dependent electric fields and no transverse current. The two states have the same properties with respect to spin-accumulation and spin-Hall angle, but not with respect to the total power dissipated.

The application of the second law of thermodynamics allows a reformulation of the problem in the form of a variational principle under constraints (Kirchhoff-Helmholtz principle). The constraints include charge accumulation and spin-flip scattering. The stationary state is then defined univocally: the first state S1 is found for the Corbino disk while the second state S2 is found for the Hall bar [2].

[1] J.-E. Wegrowe, J. Phys.: Cond Matter 29, 485801 (2017). [2] J.-E. Wegrowe, R. Benda, M. J. Rubì, Europhys. Lett. 18, 67005 (2017).

MA 41: Surface magnetism I

Time: Thursday 9:30–12:45 Location: EB 202

MA 41.1 Thu 9:30 EB 202

Magnetic properties of the $HoAu_2$ surface alloy — •Maxim Ilyn[1,2], Maria Blanco-Rey[1,3], Enrique Ortega[1,2,4], and Frederik Schiller[1,2] — [1]Donostia International Physics Center (DIPC) — [2]Materials Physics Center CSIC-UPV/EHU — [3]Department of Materials Physics, University of Basque Country UPV/EHU — [4]Department of Applied Physics, University of Basque Country

Magnetic properties of single atoms of Holmium deposited on the surface of different single crystalline substrates were a topic of active investigations in last few years. Hybridization of the Ho orbitals with electronic states of the substrate and symmetry of the crystal field were shown to be crucial in defining Ho ground state.

In this work we present results of the experimental investigation of the magnetic properties of $HoAu_2$ surface alloy. A crystal field in the position of Ho atoms in this alloy has the same C_{3v} symmetry as in the case of the Ho adsorbed on the hollow sites of (111) surface of the fcc crystal. However, the coordination is higher which results in a well-defined stable stoichiometry.

Samples prepared by deposition of Ho on the pre-heated surface of the Au(111) single crystal in the UHV environment were characterized by means of STM, LEED and ARPES. Its magnetic properties were measured in a synchrotron using XMCD spectroscopy and simulated with a help of the multiplet calculations.

MA 41.2 Thu 9:45 EB 202

Magnetic linear dichroism of ferromagnetic 3d metal thin films — •Torsten Veltum[1], Tobias Löffler[1], Stefano Ponzoni[2], Mirko Cinchetti[2], and Mathias Getzlaff[1] — [1]Institut für Angewandte Physik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf — [2]Experimentelle Physik VI, Fakultät Physik, Technische Universität Dortmund, 44221 Dortmund

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 ferromagnetic 3d metal 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 for iron and cobalt and extended to angle-resolved spectra in off-normal geometry. For iron and cobalt, the resonance between the 3d core-levels and the valence band of these materials shows an influence on the dichroism, whereas for nickel there is no influence.

MA 41.3 Thu 10:00 EB 202

Layer-specific magnetic excitations in Fe/Co multilayers — •Sergey Tsurkan, Huajun Qin, and Khalil Zakeri Lori — Heisenberg Spin-dynamics Group, Physikalisches Institut, Karlsruhe Institute of Technology, Wolfgang-Gaede-Str. 1, D-76131 Karlsruhe, Germany

We investigate the terahertz magnetic excitations in multilayers of Fe-and Co epitaxially grown on W(110). The experiments were performed by means of spin-polarized high-resolution electron energy-loss spectroscopy. Different magnon modes were observed and assigned to the excitations localized in different layers. We discuss the origin of the observed magnon modes based on a simple Heisenberg model. The model indicates that the Heisenberg exchange constants are strongly layer dependent. By probing the dispersion relation of these magnon modes over the surface Brillouin zone we quantify the strength of the exchange interaction in different layers [1]. Finally we address the effect of the Dzyaloshinskii–Moriya interaction on the observed magnon modes. [1] Zakeri, J. Phys. Condens. Matter **29**, 013001 (2017). The work has been supported by the Deutsche Forschungsgemeinschaft (DFG) through the Heisenberg Programme ZA 902/3-1 and the DFG grant ZA 902/4-1.

MA 41.4 Thu 10:15 EB 202

Theoretical studies of 2D-materials adsorbed onto magnetic surfaces — •Nicolae Atodiresei, Vasile Caciuc, and Stefan Blügel — Peter Grünberg Institut (PGI-1) and Institute for Advanced Simulation (IAS-1), Forschungszentrum Jülich, Germany

Using density functional theory calculations we explored how the interaction between magnetic surfaces with 2D materials as graphene (Gr) and transition metal dichalcogenites (TMDs) monolayers reciprocally modifies their electronic and magnetic properties. On one hand, the 2D material–substrate chemisorption induces a spin–unbalanced electronic structure of the 2D material with specific system dependent features. On the other hand, the strong hybridization at the hybrid interface leads to an increase of the magnetic exchange interactions between the surface magnetic atoms as compared to those of the clean substrate. Similarly to the case of organic molecules adsorbed on magnetic surfaces, the presence of the magnetic hardening effect at the 2D material–substrate interface emphases the generality of this adsorbate induced–effect on magnetic surfaces.

This work is supported by DFG through SFB 1238 (Project C01).

[1] M. Callsen *et al.*, Phys. Rev. Lett. **111**, 106805 (2013).
[2] R. Decker *et al.*, J. of Phys.: Cond. Matter. **26**, 394004 (2014).
[3] R. Brede *et al.*, Nature Nanotech. **9**, 1018 (2014).
[4] F. Huttmann *et al.*, Phys. Rev. Lett. **115**, 236101 (2015).
[5] F. Huttmann *et al.*, Phys. Rev. B **95**, 075427 (2017).

MA 41.5 Thu 10:30 EB 202

Excited spin-state trapping in spin crossover complexes on ferroelectric substrates — Christian Wäckerlin[1,2], Fabio Donati[3,4], Aparajita Singha[1], Romana Baltic[1], Silvio Decurtins[5], Shi-Xia Liu[5], Stefano Rusponi[1], and •Jan Dreiser[1,6] — [1]Ecole Polytechnique Federale de Lausanne, 1015 Lausanne, Switzerland — [2]Swiss Federal Laboratories for Materials Science and Technology, 8600 Dübendorf, Switzerland — [3]Institute for Basic Science, Seoul 03760, Republic of Korea — [4]Ewha Womans University, Seoul, Republic of Korea — [5]University of Bern, 3012 Bern, Switzerland — [6]Paul Scherrer Institut, 5232 Villigen PSI, Switzerland

Spin crossover molecules exhibit a switchable spin state. Combining them with inorganic ferroelectrics represents a promising path toward magnetoelectric devices. Here we report on a study of films of Fe(II) spin crossover molecules deposited on differently poled ferroelectric PMN-PT ($[Pb(Mg_{1/3}Nb_{2/3})O_3]_{1-x}$ $[PbTiO_3]_x$, $x = 0.32$). X-ray absorption spectroscopy shows complete temperature driven conversion between high-spin and low-spin states independent of the substrate ferroelectric polarization down to 100 K. However, at $T = 3$ K, in the regime of soft X-ray induced excited spin-state trapping (SOXIESST), the cross section for the SOXIESST process varies by more than one order of magnitude between the two ferroelectric polarizations. We explain our findings by the internal electric fields of the substrates modulating the scattering of X-ray generated secondary electrons at the molecules.

MA 41.6 Thu 10:45 EB 202

Step Edge Induced Anisotropic Chiral Spin Coupling Observed in Ultrathin Magnetic Films — •Stefan Krause, Anika Schlenhoff, and Roland Wiesendanger — Department of Physics, University of Hamburg, Germany

Breaking the symmetry at planar interfaces and surfaces results in a chiral spin coupling due to Dzyaloshinskii-Moriya interactions (DMI), driven by spin-orbit coupling. DMI stabilize an inhomogeneous right-rotating cycloidal spin spiral ground state in the Fe double layer (DL) on W(110), as has been demonstrated by means of spin-polarized scanning tunneling microscopy (SP-STM) [1]. In contrast, the Fe monolayer (ML) on W(110) is found to be ferromagnetic [2].

An atomic step edge separating DL and ML areas of coverage results in a breaking of the lateral symmetry of the film, potentially giving rise to localized additional DMI. In our SP-STM experiments we investigate the spin configurations around Fe/W(110) ML/DL step edges. The data give clear indications for a chiral spin coupling of the DL to the ML. Depending on the step edge orientation, the DL spin texture is locally affected by a deformation of the spin spiral and selection rules for the formation of 90° domain walls. Interestingly, an inversion of the spin coupling chirality is found for step edges oriented along the [001] and close-packed crystallographic directions, respectively. The SP-STM data will be presented and discussed in terms of anisotropic chiral spin coupling of the DL to the ML.

[1] S. Meckler *et al.*, Phys. Rev. Lett. **103**, 157201 (2001).
[2] M. Pratzer *et al.*, Phys. Rev. Lett. **87**, 127201 (2001).

15 minutes break

MA 41.7 Thu 11:15 EB 202

Hot electrons interacting with non-collinear surface spins — •Anika Schlenhoff, Stefan Krause, and Roland Wiesendanger — Department of Physics, University of Hamburg (Germany)

Understanding the interactions of hot electrons with localized spins is an important prerequisite for the development of spintronic applications. An ideal model system to investigate these interactions are image-potential states (IPS) forming a Rydberg-like series of unoccupied exchange-split states in front of a magnetic surface. While IPS on ferromagnetic systems have been investigated [1,2], their electronic structure on non-collinear magnets is yet not explored.

In our experiments, we use a spin-polarized scannning tunneling microscope (SP-STM) in the field emission mode to locally investigate IPS above non-collinear spin textures. Our studies on the double layer (DL) Fe/W(110) spin spiral, the DL Fe/Ir(111) spin spiral and the monolayer Fe/Ir(111) nano-skyrmion lattice reveal the IPS exhibiting the local spin quantization axis of the underlying surface, rotating on the lateral atomic-scale. High-order IPS located 10 nm away from the surface still reflect the non-collinear spin texture, allowing for atomic-scale magnetic imaging at unprecedented large tip-sample distances. Our experiments indicate that the exchange-correlations between hot electrons with about 20 eV and bulk electrons in non-collinear thin-film magnets are governed by the interplay of Heisenberg exchange, Dzyaloshinskii-Moriya, spin-orbit and four-spin interaction.

[1] M. Donath *et al.*, Surf. Sci. **601**, 5701 (2007).
[2] A. Schlenhoff *et al.*, Phys. Rev. Lett. **109**, 097602 (2012).

MA 41.8 Thu 11:30 EB 202

Slowing down magnetization relaxation of lanthanide phthalocyanine double and triple deckers using a thin oxide film — •Michał Studniarek[1], Aparajita Singha[2], Romana Baltic[2], Christian Wäckerlin[2], Katharina Diller[2], Fabio Donati[2,3,4], Yanhua Lan[5], Svetlana Klyatskaya[5], Mario Ruben[5], Stefano Rusponi[2], Harald Brune[2], and Jan Dreiser[1] — [1]PSI, Villigen, Switzerland — [2]EPFL, Lausanne, Switzerland — [3]Inst. f. Basic Science, Seoul, Republic of Korea — [4]Ewha Womans Univ., Seoul, Republic of Korea — [5]KIT, Eggenstein-Leopoldshafen, Germany

Recently, Wäckerlin *et al.* demonstrated a three-Tesla magnetic hysteresis opening on a submonolayer of $TbPc_2$ single-ion magnets (SIMs) on a thin MgO film [1] opening a new pathway for applications of surface adsorbed SIMs. To check for the generality of this approach and to grasp the role of the insulating film we performed similar experiments on $DyPc_2$ and Tb_2Pc_3. X-ray circular dichroism measurements at 3 K of $DyPc_2$ and Tb_2Pc_3 on MgO/Ag(100) revealed unprecedentedly large openings of magnetic hysteresis loops. However, the enhancement of the coercivity of these molecules on MgO is less pronounced compared to the one observed for $TbPc_2$. Besides, we demonstrate an increased blocking temperature of $DyPc_2$/MgO compared to, *e.g.*, $DyPc_2$/HOPG, what is not observed for $TbPc_2$. Finally, in this talk I will discuss the effect of the substrate phonon density of states and of the molecular symmetry on the magnetization dynamics in the light of this new study.

[1] Wäckerlin *et al.*, *Adv. Mater.* **28**, 5142 (2016)

MA 41.9 Thu 11:45 EB 202

X-ray spectroscopy of simple transition-metal–oxygen model systems — •Vicente Zamudio-Bayer[1,2], Rebecka Lindblad[1,3], Christine Bülow[2], Martin Timm[2], Konstantin Hirsch[2], Arkadiusz Ławicki[2], Akira Terasaki[4], Bernd von Issendorff[1], and Tobias Lau[2] — [1]Physikalisches Institut, Universität Freiburg, 79104 Freiburg, Germany — [2]Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie, 12489 Berlin, Germany — [3]Department of Physics, Lund University, 22100 Lund, Sweden — [4]Department of Chemistry, Kyushu University, Fukuoka 812-8581, Japan

In the recent literature (Rau et al., Science 344, 988) it was demonstrated that a cobalt adatom on an MgO layer shows a record high magnetic anisotropy energy with an out-of-plane easy axis. The symmetry of the system is dominated by the uniaxial configuration of the cobalt atom on top of the oxygen site. With the dominating uniaxial configuration in mind, we have performed x-ray absorption and x-ray magnetic circular dichroism spectroscopy on free, diatomic ions consisting of a 3d metal and an oxygen atom ($TM\text{-}O^+$ with TM = Mn, Fe, Co, Ni, Cu). We are thus able to study, at a fixed symmetry, trends and correlations between electronic configuration, orbital magnetic moment, and spin polarization in this model oxide systems. Moreover, we gain an improved understanding of how the interplay between symmetry, orbital occupation, and charge-transfer excitations influence the shape of the x-ray absorption spectra. Possible consequences of large MAE for the magnetization of free particles will also be discussed.

MA 41.10 Thu 12:00 EB 202

Large tunneling anisotropic magnetoresistance mediated by surface states — •Marie Hervé[1], Timofey Balashov[1], Arthur Ernst[2], and Wulf Wulfhekel[1] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, Wolfgang-Gaede-Strasse 1, 76131 Karlsruhe, Germany — [2]Institute for Theoretical Physics, Johannes Keppler University Linz, Altenberger Strasse 69, 4040 Linz, Austria

Tunneling anisotropic magnetoresistance (TAMR) is an effect originating from the spin-orbit coupling (SOC). It is related to changes in the density of state of a magnetic layer upon changes of the magnetization axis. It has been observed in a large variety of magnetic thin films. In this communication we report on a large TAMR effect (up to 30 %) observed in hcp Co using scanning tunneling microscopy. With the help of ab initio calculations the TAMR can be traced back to the spin-polarized occupied surface state of Co which experiences a strong spin-orbit interaction.

MA 41.11 Thu 12:15 EB 202

Tunneling anisotropic magnetoresistance via molecular π orbitals of Pb dimers — Johannes Schöneberg[1], Paolo Ferriani[2], •Stefan Heinze[2], Alexander Weismann[1], and Richard Berndt[1] — [1]Institute of Experimental Physics, Christian-Albrechts-Universität zu Kiel, Germany — [2]Institute of Theoretical Physics and Astrophysics, Christian-Albrechts-Universität zu Kiel, Germany

Tunneling anisotropic magnetoresistance (TAMR) [1,2] has been observed down to the single atom limit [3]. However, so far mostly 3d transition-metals with a considerable magnetic moment have been studied. Here, we demonstrate a large TAMR for individual Pb dimers on a ferromagnetic surface due to molecular π orbitals. Dimers oriented differently with respect to the magnetization directions of a ferromagnetic Fe double layer on W(110) were made with a scanning tunneling microscope. Depending on the dimer orientations, TAMR is absent or as large as 20% at the Fermi level. General arguments and first-principles calculations show that mixing of molecular orbitals due to spin-orbit coupling, which leads to TAMR, is maximal when the magnetization is oriented parallel to the dimer axis.

[1] M. Bode *et al.*, Phys. Rev. Lett. **89**, 237205 (2002).
[2] C. Gould *et al.*, Phys. Rev. Lett. **93**, 117203 (2004).
[3] N. Néel *et al.*, Phys. Rev. Lett. **110**, 037202 (2013).

MA 41.12 Thu 12:30 EB 202

Elliptical spin excitations by engineering the magnetic interactions of Fe adatoms and dimers on Cu(111) — •Filipe Souza Mendes Guimarães, Manuel dos Santos Dias, Benedikt Schweflinghaus, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

We investigate the role of spin-orbit coupling on the spin dynamics of Fe adatoms and dimers deposited on the Cu(111) [1]. The spin excitations of an Fe adatom can be surprisingly anisotropic and may be controlled either via a large in-plane external magnetic field, or by

forming a dimer with a neighboring Cu adatom, as previously shown on a semi-insulating surface [2]. We also consider spin excitations of two kinds of Fe dimers. While the dimer with nearest-neighbor separation is strongly ferromagnetic, and its lowest spin excitation can be described as the elliptical precession of a giant spin with biaxial magnetic anisotropy, the one with twice the separation has an antiferromagnetic ground state but also present a ferromagnetic metastable state thanks to the magnetic anisotropy. For the latter, we explore the spin excitations from both kinds of magnetic states, and propose that the metastable state can be accessed with a pump-probe STM experiment [2]. This work is supported by the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator grant 681405 – DYNASORE).
[1] F. S. M. Guimarães *et al.*, Phys. Rev. B **96**, 144401 (2017)
[2] S. Loth *et al.*, Science **329**, 1628 (2010)

MA 42: Thin films – anisotropy

Time: Thursday 9:30–12:30 Location: EB 301

MA 42.1 Thu 9:30 EB 301

Magnetic properties of Co/Pt multilayers and their dependence on Co thickness — •Lorenzo Fallarino[1], Karine Chesnel[2], Benny Böhm[3], Fabian Samad[3], and Olav Hellwig[1,3] — [1]Institute of Ion Beam Physics and Materials Research, HZDR — [2]Department of Physics and Astronomy, BYU, USA — [3]Institute of Physics, TU Chemnitz

Ferromagnetic (FM) / non-magnetic multilayers with perpendicular magnetic anisotropy (PMA) provide an efficient route for controlling magnetism. They constitute an interesting model system with easily tunable magnetic properties by changing the individual layer thicknesses or number of repetitions[1]. During the past years, an extensive work effort has led to an apparently complete understanding of those structures. The majority of these studies utilized very thin FM layers, since an in-plane reorientation of the magnetization is expected for thicker films. However, for sufficiently thick FM layers, the system undergoes a second transition back to out-of-plane direction[2]. Consequently, we present a thickness dependent study of magnetic properties of $[Co/Pt]_{50}$ multilayers that maintain their PMA through all Co thicknesses. By studying in more detail the influence of the magnetic history on the remanent domain pattern[3], we find an optimal Co thickness for that instead of the typical maze-like inter-connected domains a bubble lattice is stabilized with extraordinary high domain density[4].
[1] M. T. Johnson et al. Rep. Prog. Phys. **59**, 1409 (1996). [2] L. Fallarino et al. PRB **94**, 064408 (2016). [3] Westover et al. JMMM **399**, 164 (2016). [4] K. Chesnel et al. submitted to PRB (25/08/2017).

MA 42.2 Thu 9:45 EB 301

Tunable magnetic properties in perpendicularly magnetized Mn-Fe-Ga tetragonal Heusler for spintronic applications — •Adel Kalache[1], Anastasios Markou[1], Gerhard H. Fecher[1], Susanne Selle[2], Thomas Höche[2], and Claudia Felser[1] — [1]Max Planck Institut CPFS, Dresden, Germany — [2]Fraunhofer Institute for Microstructure of Materials and Systems IMWS, Halle, Germany

Perpendicular magnetic anisotropy was studied in tetragonal $D0_{22}$ Mn-Fe-Ga thin films on different substrates as candidates for spintronic applications. By varying the Mn/Fe ratio, it is possible to tune the magnetic properties such as magnetization and coercivity, while retaining out-of-plane anisotropy over large composition range. The substitution of Fe in $Mn_{2.6-x}Fe_xGa_{1.4}$ maximizes the magnetic anisotropy at a Fe content of $x = 1$. Transmission electron microscope investigations confirmed the single crystalline nature of the film as well as the homogeneity by elemental mapping using EDXS. We emphasize that a careful control over composition, in this case Ga content, is essential to tailor the magnetic properties in Heusler thin films. These findings are expected to benefit the integration of tetragonal Heusler compounds into spintronic devices.

MA 42.3 Thu 10:00 EB 301

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

X-ray absorption spectroscopy (EXAFS, XANES, and XMCD) at K and $L_{2,3}$ edges of Fe as well as K edge of Al together with synchrotron-based diffraction has been applied to probe local rearrangements and related magnetic and electronic properties of Fe and Al atoms in bare $Fe_{60}Al_{40}$ thin films through the order-disorder (B2 $\rightarrow$ A2) phase transition. Distinct changes of Fe and Al coordination resulting in increased Fe $3d$ spin polarization and characteristic changes in electronic structure of Al due to disordering created by 20 keV Ne^+ ions of (0.75 - 6)$\times 10^{14}$ ions$\cdot$cm^{-2} fluences have been demonstrated. The preferential in-plane magnetic anisotropy and variations in coercivity fields depending on temperature and irradiation fluence has been found by element-specific hysteresis loops. An attempt to reduce the top oxide layer by an inductively coupled hydrogen plasma has shown that a use of the capping layer could further increase the macroscopic magnetization of films. A theory support was provided by self-consistent DFT calculations using VASP program package.

MA 42.4 Thu 10:15 EB 301

Effect of N, C and B interstitials on the structural and magnetic properties of alloys with Cu_3Au-structure — •Ingo Opahle, Harish Kumar Singh, and Hongbin Zhang — TU Darmstadt, Germany

High-throughput density functional calculations are used to investigate the effect of interstial B, C and N atoms on the stability, structural and magnetic properties of 21 reported alloys crystallizing in the cubic Cu_3Au structure. For 29 alloy/interstitial combinations the formation of stable interstitial alloys with interstitial concentrations above 5% is expected. The majority of stable interstitials prefers the anti-perovskite structure. It is shown that interstitials can have a huge impact on the magneto-crystalline anisotropy energy (MAE) when the cubic symmetry is broken. For $MnNi_3$ and $FeNi_3$ interstitial N leads to a tetragonal distortion with a moderate uniaxial MAE. Mn_3XN_x (X=Rh, Ir, Pt and Sb) are identified as alloys with strong magneto-crystalline anisotropy. For Mn_3Ir interstitial N leads to a huge enhancement of the MAE. It is expected that N has also a strong influence on the MAE of amorphous Mn_3Ir, which is one of the state-of-the-art materials for exchange bias in hard magnetic films. The impact of the N interstitials on the MAE is discussed at hand of the electronic structure.

MA 42.5 Thu 10:30 EB 301

Electric field controlled domain wall dynamics and magnetic easy axis switching in liquid gated CoFeB/MgO films — Yuting Liu[1], Shimpei Ono[2], Guillaume Agnus[1], Samridh Jaiswal[3], Juergen Langer[3], Berthold Ocker[3], Dafiné Ravelosona[1], and •Liza Herrera Diez[1] — [1]Centre de Nanosciences et de Nanotechnologies, CNRS, Univ. Paris-Sud, Université Paris-Saclay, C2N-Orsay, 91405 Orsay cedex, France. — [2]Central Research Institute of Electric Power Industry, Komae, Tokyo 201-8511, Japan. — [3]Singulus Technology AG, Hanauer Landstrasse 103, 63796 Kahl am Main, Germany.

We present reversible electric (E) field driven switching of the magnetic easy axis in $CoFeB/MgO/HfO_2$ heterostructures from perpendicular to in-plane using an ionic liquid (IL) gate. The modification of magnetic anisotropy reaches 0.108 mJ/m^2 in a gate voltage range between -3 V and +3.5 V with an efficiency of 82 fJ(Vm)$^{-1}$. The influence of the E-field induced anisotropy changes on domain nucleation and propagation of magnetic domain walls has also been studied in the perpendicular anisotropy state. A significant modulation of the domain wall velocity is observed both in the creep and depinning regimes of domain wall motion consistent with the E-field induced anisotropy variation. In addition, we demonstrate voltage controlled magnetization switching under a constant magnetic field and voltage control of domain wall pinning.

15 minutes break

MA 42.6 Thu 11:00 EB 301

Temperature dependent magnetocrystalline anisotropy model for $La_{0.7}Sr_{0.3}MnO_3$ thin films grown on $SrTiO_3$ (001) and $NdGaO_3$ (110) substrates — •Camillo Ballani, Christoph Hauser, Christian Eisenschmidt, and Georg Schmidt — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany

A well-understood magnetocrystalline anisotropy model for ferromagnetic thin films plays a crucial role in describing spin wave propagation [1], magnetization reversal processes and related effects like tunnelling anisotropic magnetoresistance (TAMR) in organic spin valves [2]. We present a study of $La_{0.7}Sr_{0.3}MnO_3$ (001) thin films epitaxially grown via Pulsed Laser Deposition (PLD) on $SrTiO_3$ (001) and $NdGaO_3$ (110) substrates, which induce tensile and non-homogeneous compressive strain in the film plane, respectively. A detailed temperature dependent model for the magnetocrystalline anisotropy in these films is derived from Ferromagnetic Resonance (FMR) measurements and SQUID magnetometry.

[1] K. Sekiguchi et al., NPG Asia Materials **9**, e392 (2017)
[2] M. Grünewald et al., Phys. Rev. B **90**, 205208 (2014)

MA 42.7 Thu 11:15 EB 301

Origin of defect induced magnetism in TiO_2 anatase probed with X-ray magnetic circular dichroism — •Markus Stiller[1], José Barzola-Quiquia[1], Pablo D. Esquinazi[1], Alpha T. N'Diaye[2], Hendrik Ohldag[3], Thomas Lautenschläger[4], and Daniel Spemann[4] — [1]Abteilung für Supraleitung und Magnetismus, Fakultät für Physik und Geowissenschaften, Universität Leipzig, Linnestr. 5, D-04103, Germany — [2]Advanced Light Source, Lawrence Berkeley National Laboratory, Berkeley, California 94720, United States — [3]SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California, 94025 USA — [4]Leibniz-Institut für Oberflächenmodifizierung e.V., Permoserstraße 15, 04318 Leipzig, Germany

The temperature and field dependence of the magnetization of epitaxial, polycrystalline undoped TiO_2 anatase thin films on $LaAlO_3$ and $SrTiO_3$ 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 with low energy (200 eV) argon ions. The irradiated anatase thin films show an increased magnetic moment and exhibit ferromagnetism at room temperature, with an easy axis parallel to the c-axis, i.e. an out-of-plane magnetization. The anisotropy depends on film orientation, phase and surface roughness as well as the energy used for defect production. XMCD measurements show that the spin polarized band is at the titanium edge, not at the O 2p band edge, at the thin film surface.

MA 42.8 Thu 11:30 EB 301

Structural and magnetic properties of thin $Tm_3Fe_5O_{12}$ layers — •Oana Ciubotariu, Helmut Karl, and Manfred Albrecht — Institute of Physics, University of Augsburg, 86159 Augsburg

The extremely low Gilbert damping parameter and the insulating nature make $Y_3Fe_5O_{12}$ (YIG) layers the best choice for spin-related experiments. However, nanometric YIG films exhibit in-plane magnetic easy axis due to strong shape anisotropy. Nonetheless, $Tm_3Fe_5O_{12}$ (TmIG) has been reported to poses an out-of-plane magnetic easy axis when grown on $Gd_3Ga_5O_{12}$ (GGG) or substituted GGG (SGGG) substrates [1, 2]. In order to obtain high quality iron garnets, besides optimizing the substrate temperature or the oxygen pressure during growth, the cooling down procedure to room temperature after deposition has to be addressed. Here, we present the effect of the cooling down procedure on the structural and magnetic properties of TmIG layers. 100-nm thick films are grown by pulsed laser deposition on SGGG (111) substrates at optimized substrate temperature and oxygen pressure. After deposition, slow and fast cooling procedures are implemented. The effect on the crystal structure is investigated by X-ray diffraction and on magnetic properties by SQUID-VSM. Although the crystalline structure showed no dependence, the magnetic properties are strongly influenced. [1] A. Quindeau et al., Adv. Electron. Mater. 2017, 3, 1600376; [2] M. Kubota et al., Journal of Magnetism and Magnetic Materials, 339 (2013) 63-70.

MA 42.9 Thu 11:45 EB 301

Non-collinear chiral antiferromagnetic Mn_3Sn films — •Anastasios Markou[1], James Taylor[2], Adel Kalache[1], Peter Werner[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, Nöthnitzer Str. 40, 01187 Dresden, Germany — [2]Max Planck Institute for Microstructural Physics, Weinberg 2, 06120 Halle, Germany

Antiferromagnetic materials could represent the next step in spintronic applications, since antiferromagnets do not produce stray fields, are robust to external perturbations from magnetic fields, and show ultra-fast spin dynamics and current-induced phenomena. The non-collinear chiral antiferromagnets have attracted much interest, due to their remarkable structural, magnetic and electro-transport properties [1]. Here, we present the structural and magnetic properties of antiferromagnetic Mn_3Sn films with hexagonal $D0_{19}$ structure. For this purpose, we performed systematic X-ray diffraction (XRD), transmission electron microscopy (TEM), and magnetic characterization of films heteroepitaxially grown on appropriate substrates.

[1]A. K. Nayak *et al.*, Sc. Adv. **2**, e1501870 (2016).

MA 42.10 Thu 12:00 EB 301

Nucleation of stripe domains in ferromagnetic thin films — •Sukhvinder Singh, Haibin Gao, and Uwe Hartmann — Institute of Experimental Physics, Saarland University, Saarbrücken, Germany

Since the first observation of stripe domains in ferromagnetic films, i.e., about 50 years ago [1], the formation of these domains was considered as an abrupt transition from the in-plane to a partly out-of-plane magnetization. Domains separated either by Néel or cross-tie domain walls were supposed to be abruptly superimposed by stripes. We found that stripe domains evolve from the domain walls at a thickness well below the critical thickness [2,3]. The latter was so far considered as a threshold for the formation of stripe domains. Local modifications induced by a perpendicular anisotropy inside the domain walls and wall junctions were observed in detail. A periodically oscillating out-of-plane magnetization is formed inside the walls. This expands throughout the in-plane domains to form stripe domains all over the film. On the basis of our work, the widely used domain phase diagram [3] can now be refined.

[1] N. Saito, H. Fujiwara, and Y. Sugita, J. Phys. Soc. Jpn. 19, 1116 (1964).
[2] F. Virot, L. Favre, R. Hayn, and M. D. Kuzmin, J. Phys. D: Appl. Phys. 45, 405003 (2012).
[3] A. Holz and H. Kronmüller, Phys. Stat. Sol. (b) 31, 787 (1969).

MA 42.11 Thu 12:15 EB 301

Element-resolved vibrational density of states of FeRh thin films along the metamagnetic phase transition — •Benedikt Eggert[1], Joachim Landers[1], Soma Salamon[1], Alexandra Terwey[1], Alexander Schmeink[2], Ahmet Alatas[3], Thomas Toellner[3], Michael Y. Hu[3], Jiyong Zhao[3], E. Ercan Alp[3], Markus E. Gruner[1], Kay Potzger[2], Jürgen Lindner[2], Katharina Ollefs[1], Rantej Bali[2], Werner Keune[1], and Heiko Wende[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [3]Argonne National Laboratory, USA

B2-ordered FeRh shows a temperature induced first-order metamagnetic phase transition from the antiferromagnetic (AFM) to the ferromagnetic (FM) state. By applying ^{57}Fe nuclear resonant inelastic X-Ray scattering to epitaxial B2 ordered FeRh(001) thin films, we determined the Fe-projected vibrational density of states (VDOS) and the vibrational entropy change through the transition with and without an applied magnetic field. The Lamb-Mössbauer factor indicates that the AFM lattice is softer than the FM one [1]. In films with different thicknesses we find a small change in the VDOS due to varying film strain, induced by the MgO(001) substrate. Financial support by DFG (WE 2623/17-1) and U.S. DOE is acknowledged.

[1] M. Wolloch et al. Phys. Rev. B **94**, 174435 (2016)

MA 43: Magnetic textures I

Time: Thursday 9:30–12:15 Location: EB 407

MA 43.1 Thu 9:30 EB 407

Topological defects and emergent electromagnetism in cylindrical nanowires — •Michalis Charilaou[1], Hans-Benjamin Braun[2], and Jörg F. Löffler[1] — [1]Laboratory of Metal Physics and Technology, Department of Materials, ETH Zurich — [2]School of Physics, University College Dublin

Magnetic switching in nanoparticles, particularly with cylindrical symmetry, is associated with curling-type processes but conventional wisdom neglects topological constraints that preclude a continuous complete reversal. In this work [1] we present evidence that in cylindrical nanowires the process of athermal magnetization switching is initiated by the formation of smooth topological defects in the form of skyrmion lines. As long as the magnetization evolves continuously the switching is prevented by the skyrmion lines, effectively acting like radial exchange springs. Switching becomes irreversible only after a skyrmion line breaks into a pair of hedgehogs, which move along the wire. Importantly, the movement of the hedgehogs produces an emergent electric field of circular polarization and substantial magnitude. Hence, by considering a generic case of cylindrical magnetic particles we show that irreversibility is directly linked to the formation and dynamics of topological point-defects.

[1] M. Charilaou, H.-B. Braun, J. F. Löffler, arXiv:1711.03511

MA 43.2 Thu 9:45 EB 407

Spin-polarized STM study of the Fe monolayer on Rh(111) — •Markus Böhme[1], Jens Kügel[1], Martin Schmitt[1], Nicolai Seubert[1], Julia Küspert[1], Andreas Krönlein[1], Bandar Alonazi[2], Hamad Albrithen[2], and Matthias Bode[1] — [1]Physikalisches Institut, Experimentelle Physik II, *Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]King Abdulaziz City for Science and Technology, Riyadh, Saudi Arabia

Skyrmions in thin magnetic films stabilized by the Dzyaloshinskii-Morija interaction (DMI) have recently attracted considerable interest. Whereas Skyrmions are usually only stable in applied magnetic fields, the Fe monolayer on Ir(111) turned out to be unique as it exhibits a square lattice ground state of nano-skyrmions even without a field [1]. Here we report spin-polarized STM experiments performed on a monolayer Fe on Rh(111), a substrate that is isoelectronic and isostructural to Ir(111), but with Rh having a much smaller spin-orbit interaction than Ir and thus negligible DMI. In agreement with earlier calculations [2], which predicted a double–row-wise antiferromagnetic (↑↑↓↓) spin structure, we observe stripes oriented along ⟨110⟩-equivalent directions of the substrate. The periodicity of (1.0 ± 0.1) nm corresponds well with the expected value of 0.931 nm. These stripes exists in three orientational domains. Magnetic field-dependent data indicate that domain walls are associated with uncompensated magnetic moments that give rise to hysteresis effect due to domain wall movement.

[1] S. Heinze *et. al.*, Nature Physics **7**, 713 (2011).
[2] A. Al-Zubi *et. al.*, phys. stat. sol. (b) **248**, 2242 (2011).

MA 43.3 Thu 10:00 EB 407

Influence of hydrogen on noncollinear magnetic order in ultrathin Fe films on Ir(111) — •Levente Rózsa[1], Pin-Jui Hsu[1,2], Aurore Finco[1], Lorenz Schmidt[1], Krisztián Palotás[3,4], Elena Vedmedenko[1], László Udvardi[5], László Szunyogh[5], André Kubetzka[1], Kirsten von Bergmann[1], and Roland Wiesendanger[1] — [1]University of Hamburg, Hamburg, Germany — [2]National Tsing Hua University, Hsinchu, Taiwan, R.O.C. — [3]Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia — [4]University of Szeged, Szeged, Hungary — [5]Budapest University of Technology and Economics, Budapest, Hungary

Magnetic skyrmions have lately attracted significant research attention due to their possible applications in data storage and logic devices[1]. In ultrathin films and multilayers, most of the efforts so far have concentrated on tuning the balance between interactions preferring collinear and noncollinear ordering by the appropriate choice of magnetic materials and heavy metals with high spin-orbit coupling[2]. Based on *ab initio* calculations, here we discuss how the addition of hydrogen to an Fe double-layer on Ir(111) influences the magnetic interactions through modifying the hybridization between the ultrathin magnetic film and the heavy metal substrate[3]. This effect leads to the stabilization of the magnetic skyrmion lattice in the presence of external magnetic fields, also demonstrated in spin-polarized scanning tunneling microscopy measurements performed on the system. [1] A. Fert *et al.*, Nat. Nanotechnol. **8**, 152 (2013). [2] B. Dupé *et al.*, Nat. Commun. **7**, 11779 (2016). [3] P.-J. Hsu *et al.*, arXiv:1711.06784 (2017).

MA 43.4 Thu 10:15 EB 407

Structure and magnetism of an hydrogenated Fe monolayer on Ir(111) — •Aurore Finco[1], Pin-Jui Hsu[1,2], André Kubetzka[1], Kirsten von Bergmann[1], and Roland Wiesendanger[1] — [1]University of Hamburg, Germany — [2]National Tsing Hua University, Hsinchu, Taiwan

The incorporation of H atoms in a Fe bilayer on Ir(111) affects significantly its magnetic state. In particular, it was found that a skyrmionic phase appears when a magnetic field is applied [1].

H atoms can also be used to modify the monolayer Fe on Ir(111). Depending on the amount of hydrogen dosed, two different phases can form. One exhibits a hexagonal superstructure whereas the other one is roughly square. Spin-polarized scanning tunneling microscopy measurements reveal that these hydrogenated structures show complex nanometer-scale magnetic states which are different from the nanoskyrmion lattices found in the pristine Fe monolayer on Ir(111)[2,3]. This work thus provides a further example how to tune a non-collinear magnetic system by hydrogenation.

[1] Hsu et al, arxiv 1711.06784.
[2] Heinze et al, Nature Physics, 7, 713 (2011).
[3] von Bergmann et al, Nano Letters, 15, 3280 (2015).

MA 43.5 Thu 10:30 EB 407

Direct observation of chiral magnetic bobbers — F. Zheng[1,2], F. N. Rybakov[3], A. B. Borisov[4], D. Song[5], S. Wang[6,7], Z-A. Li[8], H. Du[6,7], •N. S. Kiselev[2], J. Caron[1,2], A. Kovács[1,2], M. Tian[6,7], Y. Zhang[6,7], S. Blügel[2], and R. E. Dunin-Borkowski[1,2] — [1]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons, Forschungszentrum Jülich, Germany — [2]Peter Grünberg Institut, Forschungszentrum Jülich, Germany — [3]Department of Physics, KTH-Royal Institute of Technology, Stockholm, Sweden — [4]M.N. Miheev Institute of Metal Physics, Ekaterinburg, Russia — [5]National Center for Electron Microscopy in Beijing, Tsinghua University, China — [6]High Magnetic Field Laboratory, Hefei, China — [7]Collaborative Innovation Center of Advanced Microstructures, Nanjing University, China — [8]Institute of Physics, Beijing, China

We report the direct observation of a new theoretically predicted hybrid particle-like magnetic state - a chiral bobber (ChB)[1] - which can be thought of as skyrmion tube, which is coupled to the surface and whose end takes the form of a Bloch point. We use quantitative off-axis electron holography to identify ChBs in a thin plate of B20-type FeGe and to find the range of their stability in a temperature-field phase diagram. We reveal two distinct mechanisms of ChB nucleation and confirm the coexistence of ChBs with ordinary magnetic skyrmions over a wide range of field, temperature and film thickness[2]. Our work provides a perspective for the practical application of ChBs in data storage technology. [1] F. N. Rybakov et al. Phys. Rev. Let. **115**, 117201 (2015). [2] F. Zheng et al. arXiv:1706.04654.

15 minutes break

MA 43.6 Thu 11:00 EB 407

Experimental Investigation into the thermomagnetic Phase Diagram of Pd/Fe/Ir(111) — •Philipp Lindner, Lennart Bargsten, Johannes Friedlein, Jonas Harm, Stefan Krause, and Roland Wiesendanger — Department Physik, Universität Hamburg, Jungiusstraße 11A, 20355 Hamburg

First individual atomic scale skyrmions have been observed in the system of an atomic layer of Fe sandwiched between an Ir(111) surface and a Pd monolayer [1].

At low temperature ($T < 8$ K), the application of an external magnetic field results in phase transitions from the spin spiral (SS) ground state to the skyrmion (SK) state (B > 1 T) and finally into the ferromagnetic (FM) state (B > 2 T). For potential spintronics applications, the thermal stability of the SK state is of high relevance.

In our study we epitaxially grew Pd nanoislands on the Fe-monolayer

on top of Ir(111) and investigated the sample system via scanning tunneling microscopy within our home-built ultra-high vacuum system, which allows the application of magnetic fields up to 3 T perpendicular to the (111) sample plane at the full temperature range of 1 K to 100 K.
We explored the thermomagnetic phase diagram and report the observation of the SK-FM transition even at $T \approx 80\,\mathrm{K}$. Additionally, indications of a disordered magnetic state at elevated temperatures are compared to a possible fluctuation-disordered state as predicted by Monte-Carlo and spin dynamics simulations [2].

[1] N. Romming *et al.*, Science **341**, 713 (2013).
[2] L. Rózsa *et al.*, Phys. Rev. B **93**, 024417 (2016).

MA 43.7 Thu 11:15 EB 407

SEMPA investigation of the Dzyaloshinskii-Moriya interaction in the single, ideally grown Co/Pt(111) interface — •Susanne Kuhrau, Edna C. Corredor, Fabian Kloodt-Twesten, Robert Frömter, and Hans Peter Oepen — Center for Hybrid Nanostructures, Universität Hamburg, Germany

The experimental investigation of the Dzyaloshinskii-Moriya interaction (DMI) of a single, ideally grown interface is compelling, as it allows the direct comparison with ab-initio calculations. We present a study of domains and domain walls in epitaxial, single-layer cobalt films on Pt(111) with a pseudomorphic, atomically flat interface by means of scanning electron microscopy with polarization analysis (SEMPA) [1], which is a surface-sensitive, vectorial imaging technique with a magnetic probing depth of < 5 atomic layers. Uncapped, thermally evaporated cobalt on a clean platinum single-crystal surface is imaged in situ in ultrahigh vacuum. For a cobalt thickness of 1.4 nm we observe Néel-like domain walls that show a fixed, counterclockwise sense of rotation indicating a strong DMI that originates from the single Co/Pt interface. From the observation of a pure Néel-like rotation, we derive a lower bound for the DMI strength of 0.5×10^{-3} J/m^2, which gives a DMI energy per interface atom larger than 0.8 meV. An upper bound for the DMI energy of 4.3 meV per interface atom is derived from the observation of stable domains at the onset of ferromagnetism at 0.3-nm Co thickness, corresponding to an average Co coverage of 1.5 monolayers.

[1] E.C. Corredor et al., Phys. Rev. B 96, 060410(R), 2017

MA 43.8 Thu 11:30 EB 407

Magnetism of Co monolayer on Pt(111) capped by 5d overlayers — •Eszter Simon[1], Levente Rózsa[2], Krisztián Palotás[3,4], and László Szunyogh[1] — [1]Budapest University of Technology and Economics, Budapest, Hungary — [2]University of Hamburg, Hamburg, Germany — [3]Institute of Physics, Slovak Academy of Sciences, Bratislava, Slovakia — [4]University of Szeged, Szeged, Hungary

We study the magnetic properties of a Co monolayer on Pt(111) surface as capped by a monolayer of 5d elements (Re, Os, Ir, Pt and Au) by determining the tensorial exchange interactions and magnetic anisotropies from first principles. We find a close relationship between the magnetic moment of the Co atoms and the nearest-neighbor isotropic exchange interaction due to the electronic hybridization between the Co and the capping layers. All overlayers decrease the magnitude of the Dzyaloshinskii-Moriya (DMI) interaction compared to the Co/Pt(111) system, while even the sign of the DMI changes in case of Ir overlayer [1-3]. We conclude that the variation of the DMI is well correlated with the change of the magnetic anisotropy energy. The unique influence of the Ir overlayer to the DMI is traced by scaling the strength of the spin-orbit coupling of Ir atoms and in terms of the $Au_{1-x}Ir_x$/Co/Pt(111) system. Our spin-dynamics simulations indicate that the magnetic ground state for Re/Co/Pt(111) is an elliptic conical spin spiral, while for the other systems it is ferromagnetic.

[1] G. Chen et al., Nat. Comm. 4, 2671 (2013)
[2] A. Hrabec et al., Phys. Rev. B 90, 020402 (2014)
[3] Gy. J. Vida et al., Phys. Rev. B 94, 214422 (2016)

MA 43.9 Thu 11:45 EB 407

Current-driven skyrmion dynamics in ultra-thin magnetic films — •U. Ritzmann[1,2], S. von Malottki[3], J.V. Kim[4], J. Sinova[2], S. Heinze[3], and B. Dupé[2] — [1]Uppsala University, Uppsala, Sweden — [2]Johannes Gutenberg University Mainz, Mainz, Germany — [3]Christian-Albrechts-Universität zu Kiel, Kiel, Germany — [4]C2N, CNRS, Université Paris-Sud, Université Paris-Saclay, Orsay, France

Skyrmions are topologically stabilized spin structures. They can be manipulated with electric current densities that are orders of magnitude lower than those required for moving domain walls. Especially, isolated magnetic skyrmions can occur in ultra-thin transition metal films at surfaces [1,2] and interfaces [3]. We have shown that skyrmions, antiskyrmions and higher order antiskyrmions exist in Pd(fcc)/Fe/Ir(111) due to a competition between magnetic interactions beyond the nearest neighbour approximation [4].

Here, we present a study on the motion of skyrmions and antiskyrmions via spin transfer torques excited by the spin Hall effect in the substrate. We will show that in general the current-driven motion of these metastable states cannot be described by a rigid body approximation and internal degrees of freedom have to be included. Furthermore, we will describe the different impact of the nature of the DMI on the motion of skyrmions and antiskyrmions [5].

[1] Romming et al., Science 341, 636 (2013); [2] Dupé et al., Nat. Commun. 5, 4030 (2014); [3] Dupé et al., Nat. Commun. 7, 11779 (2016); [4] Dupé et al., New J.Phys. 18, 055015 (2016); [5] Ritzmann et al., in preparation

MA 43.10 Thu 12:00 EB 407

Surface spin flop in synthetic layered perpendicular antiferromagnets — •Benny Böhm[1], Lorenzo Fallarino[2], and Olav Hellwig[1,2] — [1]Institute of Physics, Chemnitz University of Technology — [2]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf

In 1968 the surface spin flop transition was theoretically predicted by Mills [1] for antiferromagnetic superlattices. At a later time, Wang et al. [2] showed experimentally the surface spin flop for Fe/Cr epitaxial superlattices on MgO for in-plane uniaxial anisotropy by comparing theoretical hysteresis loops with magnetometry data.

Here we show for the first time that the surface spin flop state can occur in synthetic layered antiferromagnets with perpendicular magnetic anisotropy (PMA). PMA synthetic antiferromagnets made of Ir-coupled Co/Pt multilayer blocks exhibit different magnetization reversal behavior, depending on their exact magnetic energy balance. If the interlayer exchange energy term, which is mediated by the Ir interlayers, is tuned to be the dominating term in our system, then the synthetic antiferromagnets with even number of Co/Pt blocks reveal a surface spin flop. The magnetic reversal of systems with odd and even number of repeats are compared and discussed in relation to micromagnetic simulations. The latter indicates the possibility to extend the surface spin flop state with its vertical domain wall through the system down to remanence.

[1] D. L. Mills, *Phys. Rev. Lett.* 20, **1968**, p. 18-21
[2] R. W. Wang et al., *Phys .Rev. Lett.* 72, **1994**, p. 920-923

MA 44: Topological Insulators II (joint session TT/MA)

Time: Thursday 9:30–13:00 Location: A 053

MA 44.1 Thu 9:30 A 053

Robust spin-polarized midgap states at step edges of topological crystalline insulators — •Domenico Di Sante[1], Paolo Sessi[2], Martin Greiter[1], Titus Neupert[3], Giorgio Sangiovanni[1], Tomasz Story[4], Ronny Thomale[1], and Matthias Bode[2] — [1]Institut fuer Theoretische Physik, Universitaet Wuerzburg — [2]Experimentelle Physik II, Universitaet Wuerzburg — [3]Physik Institut, Universitaet Zuerich, Switzerland — [4]Institute of Physics, Polish Academy of Sciences, Warsaw, Poland

Topological crystalline insulators are materials in which the crystalline symmetry leads to topologically protected surface states with a chiral spin texture, rendering them potential candidates for spintronics applications. In this talk, I report on the discovery of one dimensional midgap states at odd atomic surface step edges of the three dimensional topological crystalline insulator (Pb,Sn)Se. A minimal toy model and realistic tight-binding calculations identify them as spin polarized flat bands connecting two Dirac points. The midgap states inherit stability through the two dimensional Dirac metal from the three dimensional bulk insulator. This makes (Pb,Sn)Se the first example for a crystal symmetry protected hierarchy of one and two dimensional topological modes, which we experimentally prove to result in a striking robustness to defects, strong magnetic fields, and elevated temperature.

[1] P.Sessi, D. Di Sante et. al, Science 354 1269 (2016)

MA 44.2 Thu 9:45 A 053

Quantum capacitance measurements in $BiSbTeSe_2$ 3D topological insulators — •Jimin Wang[1], Zhiwei Wang[2], Yoichi Ando[2], and Dieter Weiss[1] — [1]Institute for Experimental and Applied Physics, University of Regensburg, D-93040 Regensburg, Germany — [2]Physics Institute II, University of Cologne, Zülpicher Str. 77, 50937, Köln, Germany

We conducted low temperature quantum capacitance measurements in high quality bulk-insulating 3D topological insulators $BiSbTeSe_2$ flakes, with h-BN as protective capping layers. The density of states extracted from the gate voltage dependence of the quantum capacitance is asymmetric with respect its minimum, indicating a partly nonlinear energy dispersion. Our results can be well fitted using a linear dispersion with superimposed parabolic contributions, which are in agreement with literature [1, 2]. At magnetic fields higher than 10 T, we clearly resolve the zeroth Landau level, which can be observed at least up to 85 K. Due to impurity broadening, higher Landau levels cannot be resolved.

[1] A. A. Taskin, et al., PRL 107, 016801 (2011)
[2] T. Arakane et al., Nat. Commun. 3:636 (2012)

MA 44.3 Thu 10:00 A 053

Gate-Training Effects and Enhanced Transparency in HgTe Quantum Spin Hall Edge Channels — •Lukas Lunczer[1], Philipp Leubner[2], Hartmut Buhmann[1], and Laurens W. Molenkamp[1] — [1]Experimentelle Physik 3, Physikalisches Institut, Universität Würzburg — [2]Technische Universität Eindhoven

HgTe quantum wells are the most intensively studied 2D topological insulators. The key property of these systems is the existence of helical edge channels, which has been investigated in detail in various experiments [1,2,3]. However, the experimental observation of quantized conductance in these edge channels is limited to only very small sample dimensions (in the range of a few μm), which is not yet entirely understood. In this talk I will first discuss the influence of the size of the band gap to this limitation. One finds that an enlarged band gap does not result in a more stable quantization, as one would naively expect. We suggest that this the approach of gating affects our devices i.e. potential fluctuations prevent the sample from the bulk insulating state homogeneously. I will show that the non-quantized conductance in large samples can be influenced by hysteretic gate training and thus smoothening the potential landscape in the quantum well. On a 58 μm long pair of edge channels, this leads to a yet unseen conductance of 1.6 e^2/h, almost reaching the theoretically predicted value of 2 e^2/h.

[1] M. König et al., *Science* **318**, 766 (2007)
[2] A. Roth et al., *Science* **325**, 5938 (2009)
[3] C. Brüne et al., *Nature Physics* **8**, 485 (2012)

MA 44.4 Thu 10:15 A 053

Spectroscopy of 1D Edge States and Rashba-Split Valence Bands in Bismuthene on SiC(0001) — •Felix Reis[1], Gang Li[2,3], Raul Stühler[1], Lenart Dudy[1,4], Maximilian Bauernfeind[1], Stefan Glass[1], Werner Hanke[3], Ronny Thomale[3], Jörg Schäfer[1], and Ralph Claessen[1] — [1]Physikalisches Institut and Röntgen Research Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg, Germany — [2]School of Physical Science and Technology, ShanghaiTech University, Shanghai 201210, China — [3]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, D-97074 Würzburg, Germany — [4]Tempo Beamline, Synchtron Soleil, L'Orme des Merisiers, 91190 Saint-Aubin, France

Recently, the realization of bismuthene on the wide-gap substrate SiC(0001) was reported [1]. Theoretical analysis shows that Bi/SiC(0001) is a large-gap quantum spin Hall system, and demonstrates the pivotal role of the substrate not just for the stabilization of the monolayer film, but also for its topological properties. We investigate the spectroscopic properties with scanning tunneling spectroscopy (STS), photoemission and density-functional theory. We find a characteristic Rashba-split valence band due to the inversion symmetry breaking by the substrate. A metallic density of states exists at the bismuthene film edges near substrate steps. We will report STS investigations of the narrow 1D spatial confinement, and of the metallic spectra which show a zero-bias anomaly.

[1] F. Reis, G. Li, L. Dudy et al., *Science* **357**, 287 (2017).

MA 44.5 Thu 10:30 A 053

Probing the topological nature of SmB_6 by dynamical mean field theory — Patrik Thunström[1,2] and •Karsten Held[1] — [1]Institute of Solid State Physics, TU Wien, 1040 Vienna, Austria — [2]Department of Physics and Astronomy, Materials Theory, Uppsala University, 751 20 Uppsala, Sweden

Experiments on the presumptive topological insulator SmB_6 remain controversial and hotly debated, with largely conflicting physical interpretations. We present reliable density functional theory plus dynamical mean field theory calculations that yield a mixed valence ($4f^{5.5}$) state with a tiny bulk band gap and a Γ_1+Γ_8 ground state. The bulk states and the emerging topological surface states well agree with angular resolved photoemission spectra. Strong electronic correlations and the mixed valency severely modify the simple topological Kondo insulator picture, and explain, among others, the unusual spin texture of the topological surface states.

MA 44.6 Thu 10:45 A 053

Wigner oscillations and fractional Wigner oscillations in Luttinger liquids — •Niccolo Traverso Ziani and Bjoern Trauzettel — Institut für Theoretische Physik, Universität Würzburg

In finite electronic systems, when electron-electron interactions dominate over kinetic energy, electrons tend to form regular lattices, called Wigner molecules. While the study of the Wigner molecule in three and two spatial dimensions is most often carried out numerically, in one dimension the Luttinger liquid theory allows for analytical results. In one dimension, when interaction strength is increased from the non-interacting regime, a crossover between finite size Friedel oscillations (with wavevector $2k_F$) and Wigner oscillations (with wavevector $4k_F$) is found in the average density. Moreover, in a range of intermediate interactions, increasing temperature favours Wigner oscillations over Friedel ones. Importantly, for strong interactions, the Wigner molecule becomes an almost classical state and any dependence on the spin degree of freedom is lost. This behaviour is antithetical to the concept of spin-momentum locking characterizing the helical edges of two-dimensional topological insulators (helical Luttinger liquids). The compromise between strong interactions and spin-momentum locking leads, in helical systems, to a Wigner oscillation of fermions with fractional charge e/2. This fractional oscillation is also characterized by strongly anisotropic spin-spin correlations. In a finite size setup the fractional charges have a nontrivial interplay with Jackiw-Rebbi fractional solitons.

MA 44.7 Thu 11:00 A 053

Magnetotransport properties of 3D topological insula-

tor (TI) nanowire structures — •Kristof Moors[1], Peter Schüffelgen[2,3], Daniel Rosenbach[2,3], Tobias Schmitt[2], Thomas Schäpers[2,3], and Thomas Schmidt[1] — [1]University of Luxembourg, Luxembourg, Luxembourg — [2]Peter Grünberg Institut, Jülich, Germany — [3]Helmholtz Virtual Institute for Topological Insulators (VITI), Jülich, Germany

3D TIs host gapless spin-momentum locked surface states with great potential for applications in spin electronics or quantum computing. When confined to the surface of a straight nanowire however, a confinement-induced gap appears and the topological protection is lost. Interestingly, this protection can be restored by a magnetic field with a half-integer magnetic flux piercing the cross section of the wire. To further explore the magnetotransport properties of nanowire structures, e.g. kinks or Y-junctions, we present a 3D tight-binding model, based on the $k \cdot p$ Hamiltonian introduced by Zhang. This model allows us to study structures made of different TI materials with a potentially anisotropic and/or particle-hole asymmetric surface state spectrum. Based on band structure and ballistic transport simulations, we demonstrate a rescaling of the magnetoconductance oscillations as a function of the surface state thickness, the protection of gapless surface states from a perpendicular magnetic field and special angles of the magnetic field for which nanowire kinks and Y-junctions feature conductance resonances. These properties could be relevant in future quantum transport experiments of TI nanowire structures.

15 min. break.

MA 44.8 Thu 11:30 A 053

Direct phase transitions between $Z_n \times Z_n$ bosonic topological phases in 1+1D — •Julian Bibo[1], Ruben Verresen[1,2], and Frank Pollmann[1] — [1]Technische Universiät München — [2]Max-Planck-Institut für komplexe Systeme, Dreseden

Symmetry protected topological (SPT) phases are phases of matter without local order parameters. Instead, they are classified by how a global symmetry G acts projectively on the edges. For $G = Z_n \times Z_n$, there are $n-1$ non-trivial SPT phases. For $n \leq 4$, it has been proven that within a certain class of models there are direct transitions between adjacent phases. For $n \geq 5$, however, the expectation was that there are intermediate gapless phases instead of direct transitions. Contrary to this expectation, we argue analytically that there are direct transitions in case n is divisible by 2, 3 or 4. We numerically confirm that these transitions are not fine-tuned.

MA 44.9 Thu 11:45 A 053

Signatures of hydrodynamic transport in ribbons of Dirac material — •Oleksiy Kashuba[1], Laurens Molenkamp[2], and Björn Trauzettel[1] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, D-97074 Würzburg — [2]Physikalisches Institut (EP3), Universität Würzburg, D-97074 Würzburg

Charge transport in ribbon-shaped 2D Dirac systems is studied employing the Boltzmann equation. The dependence of the resistivity on temperature and bias is investigated. An accurate understanding of the influence of electron-electron interaction and material disorder allows us to identify a parameter regime, where the system reveals hydrodynamic transport behaviour. We point out the conditions for three Dirac fermion specific features: two-liquid hydrodynamics, pseudo-diffusive transport, and the electron-hole scattering dominated regime. It is demonstrated that for the very clean samples the Gurzhi effect, a definite indicator of hydrodynamic transport, can be observed.

MA 44.10 Thu 12:00 A 053

Helical Andreev bound states and non-sinusoidal current-phase relationship at the surface of topological insulators — •Niklas Krainovic, Grigory Tkachov, and Ewelina Maria Hankiewicz — Institute for Theoretical Physics and Astrophysics, University of Würzburg, D-97074 Würzburg, Germany

When a conventional superconductor is brought in close proximity to a three-dimensional topological insulator (3D TI), an unconventional triplet pairing is generated at the TI surface. Josephson junctions based on such hybrids support Andreev bound states (ABSs) that inherit the helical spin polarization of the normal TI, resulting in the non-sinusoidal Josephson current-phase relationship (CPR) [1,2]. Here, we present detailed analytic calculations of the non-sinusoidal CPR in the metallic regime and close to the Dirac point. The CPR exhibits strong forward skewness caused by a reflectionless transport channel perpendicular to the junction interface.

This work has been supported by the DFG Grant No TK60/4-1, by SFB 1170 8220 ToCoTronics 8221 and the ENB Graduate School on Topological Insulators.

[1] G. Tkachov, E. M. Hankiewicz, Phys. Rev. B 88, 075401 (2013).
[2] I. Sochnikov, L. Maier, C. A. Watson, J. R. Kirtley, C. Gould, G. Tkachov, E. M. Hankiewicz, C. Bruene, H. Buhmann, L. W. Molenkamp, and K. A. Moler, Phys. Rev. Lett. 114, 066801 (2015).

MA 44.11 Thu 12:15 A 053

Electrically induced quantum vortices and anyons in three-dimensional topological insulators — •Flavio Nogueira and Jeroen van den Brink — IFW Dresden

The electromagnetic response of a three-dimensional topological insulator is well known to be given by a so called axion electrodynamics, which features a magnetoelectric topological term $\alpha\theta/(4\pi^2)\mathbf{E}\cdot\mathbf{B}$ in the Lagrangian density, where θ is a 2π-periodic parameter and α the fine-structure constant. We show that a point electric charge induces a quantized vortex on the surface of a topological insulator, even if the system is not a superfluid. We derive the exact expressions for the electrically induced magnetic field and angular momentum. It is shown that the dynamics of charged particles on the surface obeys fractional statistics. We briefly discuss different experimental probes to detect this behavior.

MA 44.12 Thu 12:30 A 053

Controlling the Topological Properties of Stanene by Substrate Engineering: Realistic Modelling and Experimental Approaches — •Philipp Eck[1], Maximilian Bauernfeind[2], Marius Will[2], Domenico Di Sante[1], Lenart Dudy[2], Ronny Thomale[1], Jörg Schäfer[2], Ralph Claessen[2], and Giorgio Sangiovanni[1] — [1]Institut für Theoretische Physik und Astrophysik, Universität Würzburg, D-97074 Würzburg — [2]Physikalisches Institut and Röntgen Research Center for Complex Material Systems, Universität Würzburg, D-97074 Würzburg

Although two-dimensional (2D) group IV (C-, Si-, Ge-, Sn-) honeycomb lattices have been successfully grown on a vast number of substrates, strain, deformation and/or hybridization often destroy their topological properties. Focusing on stanene, a promising strategy is the growth on passivated SiC(0001) with a buffer layer saturating the SiC dangling bonds. We present a systematic density functional theory study of group III and V buffer layers and shed light on the buffer-stanene hybridization physics influencing the vertical stanene distance and the stanene deformation. We find for some buffer layers large equilibrium distances leading to a freestanding-stanene-like topological band structure. The theoretical study will be supported by experimental data on an Al buffer layer.

MA 44.13 Thu 12:45 A 053

Magnetization current and anomalous Hall effect for massive Dirac electrons — •Peter Silvestrov[1] and Patrik Recher[1,2] — [1]Institute for Mathematical Physics, TU Braunschweig, 38106 Braunschweig, Germany — [2]Laboratory for Emerging Nanometrology Braunschweig, 38106 Braunschweig, Germany

Existing investigations of the anomalous Hall effect, *i.e.* a current flowing transverse to the electric field in the absence of an external magnetic field, are concerned with the transport current. However, for many, *e.g.* optical, applications one needs to know the total current, including its pure magnetization part. In this paper, we employ the two-dimensional massive Dirac equation to find the exact universal total current flowing along a potential step of arbitrary shape. For a slowly varying electric field, we find the current density $\mathbf{j}(\mathbf{r})$ and the energy distribution of the current density $\mathbf{j}^{\varepsilon}(\mathbf{r})$. The latter turns out to be unexpectedly nonuniform, behaving like a δ-function at the border of a classically accessible area at energy ε. To demonstrate explicitly the difference between the magnetization and transport currents, we consider the transverse shift of an electron ray in an electric field.

MA 45: Ferroics and Multiferroics (joint session KFM/TT/MA)

Time: Thursday 9:30–13:30 Location: EMH 225

MA 45.1 Thu 9:30 EMH 225

A piezoresponse force microscopy study of Bi(Fe,Sc)O3 multiferroic ceramics — •Vladimir Shvartsman[1], Andrei Salak[2], Dmitry Khalyavin[3], and Doru Lupascu[1] — [1]Institute for Material Science, University of Duisburg-Essen, Essen, Germany — [2]Department of Materials and Ceramic Engineering/CICECO, University of Aveiro, Aveiro, Portugal — [3]ISIS Facility, Rutherford Appleton Laboratory, Chilton, Didcot, UK

Bismuth ferrite (BFO) has attracted an immense attention as a rare room-temperature single-phase multiferroics. The magnetic and ferroelectric structure of BFO can be tuned by cationic substitutions. In particular, using the high-pressure synthesis method BiFe(1-x)Sc(x)O3 ceramics can be sintered. The material appears in different polymorphs. The phase obtained by quenching under pressure is antipolar, but can be irreversibly turned into a polar one by thermal cycling at normal pressure. The resulting modification is a rare example of coexistence of canted ferroelectric and ferromagnetic states. We have addressed ferroelectric properties of these materials by piezoresponse force microscopy (PFM). The post-annealed Bi(Fe0.5Sc0.5)O3 ceramics show a strong PFM signal and posses a well-developed domain pattern typical of a ferroelectric state. The quenched ceramics, however, demonstrate no piezoresponse that is in line with its antiferroelectric state. We found that this state can be transferred to a ferroelectric one by application of a strong enough electric field. The temporal and temperature stability of the induced states are studied.

MA 45.2 Thu 9:50 EMH 225

Electronic Ferroelectricity in Organic Charge-Transfer Salts — •Jonas K. H. Fischer[1], Peter Lunkenheimer[1], Rudra Manna[2,3], Harald Schubert[3], Jens Müller[3], Michael Lang[3], Stephan Krohns[1], John A. Schlueter[4], Cecile Mézière[5], Patrick Batail[5], and Alois Loidl[1] — [1]Experimental Physics V, EKM, University of Augsburg, Augsburg, Germany — [2]Department of Physics, IIT Tirupati, Tirupati 517506, India — [3]Phys. Inst. Univ. Frankfurt, SFB/TR 49, Frankfurt, Germany — [4]Materials Research, National Science Foundation, Arlington, Virginia, United States — [5]Laboratoire MOLTECH, UMR 6200 CNRS-Université d'Angers, Bt. K, UFR Sciences, Angers, France

The often intriguing dielectric properties of the EDT-TTF-based charge-transfer salts have attracted considerable attention in recent years [1]. Examples are κ-(BEDT-TTF)$_2$Cu[N(CN)$_2$]Cl, which exhibits multiferroicity [2], as well as α-(BEDT-TTF)$_2$I$_3$, which shows the signature of relaxor-ferroelectric behavior [1].
Here, we will present an overview of the dielectric properties of the above systems and provide new results on κ-(BEDT-TTF)$_2$Hg(SCN)$_2$Cl, which also shows ferroelectric behavior in its charge-ordered state. In addition, further organic candidates for ferroelectricity as well as recent results on δ-(EDT-TTF-CONMe$_2$)$_2$Br are presented. The latter compound exhibits charge order but lacks dimerization. It displays interesting glasslike relaxation dynamics.

[1] P. Lunkenheimer and A. Loidl, J. Phys.: Condens. Matter **27**, 373001 (2015). [2] P. Lunkenheimer *et al.*, Nat. Mater. **11**, 755 (2012).

MA 45.3 Thu 10:10 EMH 225

Superconductivity and ferroelectric quantum criticality in KTaO3 — •Tobias Esswein, Awadhesh Narayan, and Nicola Spaldin — Materials Theory, ETH Zurich, Wolfgang-Pauli-Strasse 27, CH-8093 Zurich, Switzerland

Electron doped cubic perovskite KTaO3 has recently been shown to become superconducting [1]. In the closely related material SrTiO3, a ferroelectric quantum critical point was proposed to be the origin of superconductivity [2]. In this work, using first-principles calculations, we show that a ferroelectric quantum critical point emerges with electron doping in KTaO3, lying at doping values close to the top of the superconducting dome. We examine the effects of larger spin-orbit coupling and absence of crystal field splitting in KTaO3, in comparison to SrTiO3, on the phonon spectrum, electron-phonon coupling and quantum oscillations. Our findings contribute to the growing understanding of superconductivity around quantum critical points and could help in designing materials with higher superconducting critical temperatures.

[1] Ueno, K. et al. Discovery of Superconductivity in KTaO3 by Electrostatic Carrier Doping. Nature Nanotechnology 6, 408 (2011). [2] Edge, J. M., Kedem, Y., Aschauer, U., Spaldin, N. A. & Balatsky, A. V. Quantum Critical Origin of the Superconducting Dome in SrTiO3. Physical Review Letters 115, 247002 (2015).

MA 45.4 Thu 10:30 EMH 225

In-operando study of polarization reversal in ferroelectric thin films — •Christelle Kwamen[1], Matthias Rössle[2], Matthias Reinhardt[1], Wolfram Leitenberger[2], Flavio Zamponi[2], Marin Alexe[3], and Matias Bargheer[1,2] — [1]Helmholtz Zentrum Berlin — [2]Institute of physics and astronomie, University of Potsdam — [3]Department of physics, University of Warwick

The mechanisms associated with polarization reversal in ferroelectric materails are still under investigations because the microscopic dynamics are not yet fully understood. The permanent quest for energy efficient technologies drives investigations on making a ferroelectric operational under lowest switching voltage. There are many studies which investigate either the electrical signature of the switching or the structural changes of the crystal lattice associated with the switching. We present here a simultaneous study of the electrical and structural responses of a lead-zirconate-titanate-based capacitor heterostructure during charging, discharging, and polarization reversal, using time-resolved X-ray diffraction. Concomitant with the ferroelectric current peak, we observe the switching is characterized by a transient disorder evidenced by a decrease of the Bragg peak intensity. A peak width increase reveals the domain dynamics during the reversal. Our investigations show how the incomplete screening of the depolarization charges affect the piezoelectric response, measured via the Bragg peak position. We examine the interplay between charge flow, atomic motion in real time during device operation. We investigate how ultrashort laser pulse excitation can increase the charge flow in a biased device.

MA 45.5 Thu 10:50 EMH 225

Domains Properties in Thin Ferroelectric Films Related to Surface Screening, Flexoelectric and Vegard Effects — •Ivan S. Vorotiahin[1,2], Anna N. Morozovska[2], Eugene A. Eliseev[3], Sergei V. Kalinin[4], Qian Li[4], Yevhen M. Fomichov[3,5], and Yuri A. Genenko[1] — [1]Institut für Materialwissenschaft, Technische Universität Darmstadt, Darmstadt, Germany — [2]Institute of Physics, National Academy of Sciences of Ukraine, Kyiv, Ukraine — [3]Institute for Problems of Materials Science, National Academy of Sciences of Ukraine, Kyiv, Ukraine — [4]The Center for Nanophase Materials Sciences, Oak Ridge National Laboratory, Oak Ridge, USA — [5]Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Ferroelectric domains is a topic of undying interest in the research community, since their properties and formation conditions still remain not fully understood. Among those conditions, surface screening charges, flexoelectric effect and chemical stresses can be named. Their influence is well observable in films of several to several tens of nanometres thicknesses, i.e. in the forefront of the phenomenological theories.

A series of modelling experiments has been performed to predict the effects that those physical qualities can make on a shape of ferroelectric domains in the most well-known perovskite materials, as well as their impact on the electromechanical properties, phase diagrams, and field distributions. Their influence has been numerically and analytically estimated to provide a roadmap for future measurements and compared with each other to obtain a stronger understanding of the physical processes occurring in perovskites.

MA 45.6 Thu 11:10 EMH 225

Screening in metallized ferroelectrics — •Hongjian Zhao[1], Alessio Filippetti[2,3], Carlos Escorihuela-Sayalero[1], Pietro Delugas[4], Enric Canadell[5], Laurent Bellaiche[6], Vincenzo Fiorentini[2,3], and Jorge Íñiguez[1] — [1]Materials Research and Technology Department, Luxembourg Institute of Science and Technology, Luxembourg — [2]Dipartimento di Fisica, Università di Cagliari, Cittadella Universitaria, Italy — [3]CNR-IOM SLACS, Cittadella Universitaria, Italy — [4]Scuola Internazionale Superiore di Studi Avanzati, Italy — [5]Institut de Ciència de Materials de Barcelona, Spain — [6]Physics Department and Institute for Nanoscience and Engineering, University of Arkansas, USA

Ferroelectric materials are characterized by spontaneous polar distortions. The behavior of such distortions in the presence of free charge is the key to the physics of metallized ferroelectrics in particular, and of structurally-polar metals more generally. Using first-principles simulations, here we show that polar distortions resist metallization and the attendant suppression of long-range dipolar interactions in the vast majority of a sample of eleven representative ferroelectrics. We identify a novel meta-screening effect, occurring in the doped compounds as a consequence of the charge rearrangements associated to electrostatic screening, as the main factor determining the survival of a non-centrosymmetric phase. Our findings advance greatly our understanding of the essentials of structurally-polar metals, and offer guidelines on the behavior of ferroelectrics upon field-effect charge injection or proximity to conductive device elements.

20 min. break

MA 45.7 Thu 11:50 EMH 225

Pressure-induced insulator-metal transition in $EuMnO_3$ — •Andres Cano — CNRS, Univ. Bordeaux, ICMCB, Bordeaux, France

We study the influence of external pressure on the electronic and magnetic structure of $EuMnO_3$ from first-principles calculations. We find a pressure-induced insulator? metal transition at which the magnetic order changes from A-type antiferromagnetic to ferromagnetic with a strong interplay with Jahn?Teller distortions. This unexpected pressure-induced insulator-to-metal transition, although similar to the observed in CMR $LaMnO_3$, is unprecedented within the multiferroic RMnO$_3$ series. In addition, we find that the non-centrosymmetric $E^?$-type antiferromagnetic order can become nearly degenerate with the ferromagnetic ground state in the high-pressure metallic state. These features make $EuMnO_3$ an unique compound among the manganites because it behaves differently with respect to physical and "chemical" pressure, and hosts a genuinely new type of ferroelectric-like metallic state.

[1] *Pressure-induced insulator-metal transition in EuMnO3*, R. Qiu, E. Bousquet and A. Cano, J. Phys.: Condens. Matter 29, 305801 (2017).

MA 45.8 Thu 12:10 EMH 225

Far infrared studies on a diluted rare-earth langasite — •Lorenz Bergen[1], Evan Constable[1], Lukas Weymann[1], Alexander A. Mukhin[2], Nadezhda Kostyuchenko[1], and Andrei Pimenov[1] — [1]Institute of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia

Rare-earth langasites demonstrate fascinating structural and magnetic effects such as geometric frustration and are possible candidates for the spin-liquid state. To better understand the interplay between the structural and magnetic properties it is important to study the phonon and crystal electric field spectra that can be observed in the far infrared (FIR) range. The langasite structure crystallizes in the P321 space group with a general formula $A_3BC_3D_2O_{14}$. Here we present spectra of the diluted rare-earth langasite $La_{2.91}Ho_{0.09}Ga_5SiO_{14}$ using polarized far infrared radiation along different crystallographic directions and under a broad temperature range. The observed phonon frequencies are compared with model calculations. We compare the results on the holmium doped crystal and on pure $La_3Ga_5SiO_{14}$ langasite.

MA 45.9 Thu 12:30 EMH 225

Magnetic Excitations and High-Order Magnetoelectric Effect in Holmium Langasite — •Lukas Weymann[1], Thomas Kain[1], Alexey Shuvaev[1], Artem Kuzmenko[2], Alexander Mukhin[2], Evan Constable[1], Lorenz Bergen[1], Nadezhda Kostyuchenko[1], Anna Pimenov[1], and Andrei Pimenov[1] — [1]Institute of Solid State Physics, Vienna University of Technology, 1040 Vienna, Austria — [2]Prokhorov General Physics Institute, Russian Academy of Sciences, 119991 Moscow, Russia

Recently, compounds of the langasite family (prototype $La_3Ga_5SiO_{14}$) have attracted considerable attention due to their intriguing magnetic and magnetoelectric properties. The geometric frustration of the magnetic ions lies in the focus of the investigation of rare-earth langasites, since this makes them promising candidates for spin liquids.

In this work we show that in diluted rare-earth langasite $La_{2.91}Ho_{0.09}Ga_5SiO_{14}$ (3%Ho-LGS), where no magnetic frustration is present, unusual properties can be observed. 3%Ho-LGS single crystals reveal a substantial magnetoelectric effect comparable with other rare-earth langasites. The symmetry and the field dependence of the effect can only be explained by taking into account the higher order expansions of the crystal field theory. Terahertz measurements with a Mach-Zehnder interferometer reveal a series of characteristic magnetic excitations and a strong zero-field mode of presently unknown origin.

MA 45.10 Thu 12:50 EMH 225

Structural phase transition and domain formation in the hybrid improper ferroelectric $Ca_3Mn_{1.9}Ti_{0.1}O_7$ — •Mads C. Weber[1], Thomas Lottermoser[1], Morgan Trassin[1], Bin Gao[2], Sang-Wook Cheong[2], and Manfred Fiebig[1] — [1]ETH Zurich, Switzerland — [2]Rutgers University, Piscataway, New Jersey, USA

One of the bottlenecks for the application of magneto-electric multiferroics is the lack of materials with both, a robust coupling between ferroelectricity and magnetism, and a sufficiently large polarization. This problem may be overcome in layered perovskite systems, where octahedral rotations can give rise to improper ferroelectricity as well as a net-magnetization. Accordingly, ferroelectricity and magnetic order are linked by non-polar structural distortions. Essential for the understanding of the potential coupling of both parameters is an in-depth comprehension of the structural distortions and the formation of domains. In this work, we present a combined Raman spectroscopy (RS) and optical second harmonic generation (SHG) study of the improper ferroelectric phase transition and the related domain formation. Using RS, we trace the evolution of the non-polar structural distortions across the phase transition by probing the lattice vibrations of the system. Furthermore, we investigate the emergence of ferroelectricity by SHG a technique highly sensitive to breaking of inversion symmetry. Hence, RS and SHG represent a unique combination to investigate improper ferroelectric phase transitions.

MA 45.11 Thu 13:10 EMH 225

Lead Palladium Titanate: A new room-temperature magnetoelectric multiferroic — •Elzbieta Gradauskaite[1,2], Jonathan Gardner[3], Rebecca M. Smith[3], Finlay D. Morrison[3], Stephen L. Lee[1], Ram S. Katiyar[4], and James F. Scott[1,3] — [1]School of Physics and Astronomy, University of St Andrews, United Kingdom — [2]Present address: Department of Materials, ETH Zürich, Zürich, Switzerland — [3]School of Chemistry, University of St Andrews, United Kingdom — [4]Department of Physics, SPECLAB, University of Puerto Rico, USA

Magnetoelectric multiferroic materials combine the advantages of FeRAMs (speed, low power) and MRAMs (non-destructive readout) due to the linear (magnetoelectric) coupling between ferroelectricity and ferromagnetism. Despite the worldwide interest and effort, very few single-phase materials have been discovered that exhibit magnetoelectric coupling at room temperature. Until very recently $BiFeO_3$ was the only one, however it is not suitable for real practical device applications due to high leakage currents and weak coupling. Here, we demonstrate that $PbTi_{1-x}Pd_xO_3$ ($0 < x < 0.3$) is multiferroic up to 400 K and possesses a strong magnetoelectric coupling. This observation is remarkable because Pd is difficult to substitute into ABO_3 perovskite oxides and it is magnetic only under unusual conditions (strain or internal electric fields). Dielectric spectroscopy and magnetization studies will be discussed in detail, while paying particular attention to secondary phases present in the bulk specimen, identified as PdO, $PbPdO_2$ and Pd_3Pb using PXRD, SEM, EDX and XPS.

MA 46: Magnonics II

Time: Thursday 15:00–18:00 Location: H 0110

Topical Talk MA 46.1 Thu 15:00 H 0110
Topological spin textures as spin-wave emitters — •Sebastian Wintz — Paul Scherrer Institut, Villigen PSI, Switzerland — Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany

The investigation of propagating spin waves is a key topic of magnetism research [1]. For the excitation of short wavelengths, it was typically necessary to either use patterned transducers with sizes on the order of the desired wavelengths (striplines or point-contacts) or to generate such spin waves parametrically by a spatially uniform double-frequency microwave signal [2]. Recently, we found a novel mechanism for the local excitation of spin waves, which overcomes the lower wavelength limit given by the minimum patterning size. This method utilizes the translation of natural topological spin textures, e.g. the gyration of spin vortex cores, to generate spin waves [3]. Yet in terms of signal transfer, spin waves excited by a 0D defect, propagating isotropically in a 2D matrix suffer from a geometry induced amplitude decay. This decay is prevented when the dimensionality difference between source and host matrix is reduced to one. Here we will show that this can be achieved in vortex pair systems with moderate uniaxial intrinsic anisotropy, where domain walls may act both as 1D channels for directional wave propagation and as emitters for 2D plane waves [4]. Finally, we will address vortex core induced spin-wave excitation in single layer films [5]. [1] A.V. Chumak et al., Nat. Phys. 11, 453 (2015). [2] A.G. Gurevich, G.A. Melkov, Magnetization Oscillations and Waves. New York CRC, 1996. [3] S. Wintz et al., Nat. Nanotechnol. 11, 948 (2016). [4] V. Sluka et al. (unpublished). [5] G. Dieterle et al. (unpublished).

MA 46.2 Thu 15:30 H 0110
Tunable short-wavelength spin wave emission and confinement in anisotropy-modulated multiferroic heterostructures — Sampo J. Hämäläinen[1], Florian Brandl[2], Ben Van de Wiele[3], Kévin J. A. Franke[1], Dirk Grundler[2], and •Sebastiaan van Dijken[1] — [1]Department of Applied Physics, Aalto University, Finland — [2]Institute of Materials, EPFL, Switzerland — [3]Department of Electrical Energy, Ghent University, Belgium

Excitation of short-wavelength spin waves from a precise location is essential for the downscaling of magnonic devices. Here, we report on the generation and confinement of short-wavelength spin waves in a continuous film with periodically modulated magnetic anisotropy. The concept, which is demonstrated for strain-coupled CoFeB/$BaTiO_3$ heterostructures, relies on abrupt rotation of magnetic anisotropy at the boundaries of magnetic stripe domains. In combination with an external bias field, this produces a lateral variation of the effective magnetic field, leading to local spin wave excitation when irradiated by a microwave magnetic field. In domains with small effective field, spin waves are perfectly confined by the spin gap in neighboring domains. In contrast, standing spin waves in domains with large effective field radiate into neighboring domains. Using micromagnetic simulations, we show that the wavelength of emitted spin waves is tunable from a few micrometers down to about 100 nm by rotation of the bias field. We also demonstrate that dynamic fluctuations of the effective magnetic field and microwave spin-polarized currents can be used to excite exchange-dominated spin waves in multiferroic heterostructures.

MA 46.3 Thu 15:45 H 0110
Two-dimensional wave vector resolved transport measurements of magneto-elastic bosons — •Pascal Frey, Dmytro A. Bozhko, Alexander A. Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Macroscopic quantum states—Bose-Einstein condensates (BECs) can be created in overpopulated gases of bosonic quasiparticles as excitons, polaritons or magnons. However, interactions between quasiparticles of a different nature, for example, between magnons and phonons in a magnetic medium, can significantly alter the properties of these gases and thus modify the condensation scenarios. Recently, we reported on the discovery of a novel condensation phenomenon mediated by the magnon-phonon interaction: an accumulation of hybrid magneto-elastic bosons. Unlike a BEC, the accumulated magneto-elastic bosons possess a nonzero group velocity, making them promising data carriers in prospective magnon spintronic circuits. Here, we present the results of two-dimensional transport measurements of magneto-elastic bosons in a single-crystal yttrium iron garnet film. Due to the strong magnetically induced anisotropy the curvature of the magnon-phonon spectrum is changed in the hybridization area and therefore we observe several spatially localized beams with different group velocities for the magnon-phonon hybrid states. The nature of the observed beams and their relations with caustic effects is discussed. This work is supported by the European Research Council within the ERC Advanced Grant "Supercurrents of Magnon Condensates for Advanced Magnonics".

MA 46.4 Thu 16:00 H 0110
Spin waves along domain walls in magnetic dots — Antonio Lara[1], Konstantin Y. Guslienko[2,3], Jose Luis Prieto[4], and •Farkhad G Aliev[1] — [1]Universidad Autonoma de Madrid, 28049 Cantoblanco-Madrid, Spain — [2]Universidad del País Vasco, 20018 San Sebastián, Spain — [3]IKERBASQUE, 48013, Bilbao, Spain — [4]Universidad Politécnica de Madrid, 28031, Spain

We discuss quasi one-dimensional spin waves in Permalloy dots of different geometries and in different magnetic states. Recent studies allowed observation of spin waves along domain walls in rectangular, circular [1] and triangular dos in the ground or metastable states. Triangular dots could also present edge pinned inhomogeneous magnetic states, depending on the direction of the external magnetic field. These edge domain walls yield the interesting, and potentially applicable in real devices property of broadband spin waves confinement to the edges of the structure [2,3] with capabilities to be redirected at angles exceeding 100 degrees. We also show how these waves could be generalized for arbitrary shapes and propose few devices (such as interferometers, controllers or splitters) where edge spin waves could be implemented. [1] F.G. Aliev, et al., Phys. Rev. B 84, 144406 (2011); [2] A. Lara, V. Metlushko, F. G. Aliev, J. Appl. Phys. 114, 213905 (2013); [3] A. Lara, J. Robledo, K.Y. Guslienko, F. G. Aliev, Sci. Reports, 7: 5597 (2017).

MA 46.5 Thu 16:15 H 0110
Optical effects in photonic-magnonic crystals — Yulia Dadoenkova[1,2,3], Nataliya Dadoenkova[1,3], Jaroslaw Klos[4], Maciej Krawszyk[4], and •Igor Lyubchanskii[3] — [1]Ulyanovsk State University, Ulyanovsk, Russian Federation — [2]Institute of Electronics and Information Systems, Novgorod State University, Veliky Novgorod, Russian Federation — [3]Donetsk Physical and Technical Institute of the National Academy of Sciences of Ukraine, Ukraine — [4]Faculty of Physics, Adam Mickiewicz University in Poznan, 61-614 Poznan, Poland

In this communication we present the results of theoretical investigation of Faraday and Goos-Haenchen (GH) effects in one-dimensional photonic-magnonic crystals (PMC) consisting of periodically distributed magnetic layers spaced by finite size dielectric photonic crystals. We found that the Faraday rotation of p-polarized incident light is increasing in the transmission band with the number of magnetic supercells. The increase of Faraday rotation is observed also in vicinity of the band-gap modes localized in magnetic layers but the maximal polarization plane rotation angles are reached at minimal transmittivity. We studied the GH effect, i.e., the lateral shift of the light beam transmitted through PMC and show that the increase of the number of periods in the photonic-magnonic structure leads to increase of the GH shift in the vicinity of the frequencies of defect modes located inside the photonic band gaps. We also investigated an influence of the linear magnetoelectric coupling in the magnetic layers on the Faraday rotation and GH effect in PMC.

MA 46.6 Thu 16:30 H 0110
Temperature dependent relaxation of magnons in yttrium iron garnet films — •Laura Mihalceanu[1], Vitaliy I. Vasyuchka[1], Dmytro A. Bozhko[1], Thomas Langner[1], Alexey Yu. Nechiporuk[2], Vladislav F. Romanyuk[2], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Taras Shevchenko National University of Kyiv, Ukraine

The lifetime of magnons is of high relevance for the fields of magnonics, magnon spintronics and quantum computing. When approaching cryogenic temperatures, quantum phenomena in spin-wave systems pave the path towards quantum information processing. Also, an elongated magnon lifetime at low temperatures will allow to investigate the dynamics of a magnon Bose-Einstein condensates at long-time intervals. Here, the relaxation behavior of parametrically excited magnons was experimentally investigated in the temperature range from 20 K to 340 K in single crystal yttrium iron garnet (YIG) films epitaxially grown on gallium gadolinium garnet (GGG) substrates as well as in an ultrapure bulk YIG crystal. As opposed to the bulk YIG crystal in YIG films we have found a significant increase in the magnon relaxation rate below 150 K up to 10.5 times the reference value at 340 K in the entire range of probed wavenumbers. This increase is associated with rare-earth impurities contaminating the YIG samples with a slight contribution caused by coupling of spin waves to the spin system of the paramagnetic GGG substrate at the lowest temperatures. (arXiv:1711.07517) The work is supported by the DFG within the SFB/TR 49.

MA 46.7 Thu 16:45 H 0110

A spin waves optical pumping in reconfigurable magnonic crystal — Chia-Lin Chang[1], Szymon Mieszczak[2], Ronnie Tamming[1], Mateusz Zelent[1], Julius Janusonis[1], Piotr Graczyk[2], •Jarosław W. Kłos[2,3], and Raanan I Tobey[1] — [1]Zernike Institute for Advanced Materials, University of Groningen, Groningen, The Netherlands — [2]Faculty of Physics, Adam Mickiewicz University in Poznan, Poznań, Poland — [3]Ernst Moritz Arndt University, Greifswald, Germany

The laser interference pattern is used here to generate a transient magnonic crystal in Ni layer by the reduction of magnetization in periodically heated regions. The heat transferred by laser pulse produces also dynamic strain in the form of phase-locked elastic wave capable of preferentially driving precessional magnetization motion in different regions of the Ni layer. The magnetization dynamics is probed with the aid of time resolved Faraday effect. The observed spin wave dynamics is anisotropic with respect to the angle of in-plane applied magnetic field. We found that the anomalies in the angular dependence of the resonance field reveal spin wave localization effects. Calculations of the spin wave normal modes in a laterally varying magnetization landscape elucidate the localization tendencies, while an estimation of the elastic to spin wave mode excitation cross section qualitatively explains the experimental findings. Financial support from NCN Poland grants No. UMO-2012/07/E/ST3/00538 and No. UMO-2016/21/B/ST3/00452 and the EU's Horizon 2020 grant No. 644348 (MagIC).

MA 46.8 Thu 17:00 H 0110

Efficient excitation of perpendicular standing spin waves in nanometer-thick yttrium iron garnet films — •Huajun Qin, Sampo J. Hämäläinen, and Sebastiaan van Dijken — NanoSpin, Department of Applied Physics, Aalto University School of Science, P.O.Box15100, FI-00076Aalto, Finland

Spin waves in ferrimagnetic yttrium iron garnet (YIG) films are promising for low-power wave-like computing and magnon-based spintronics. The excitation frequency of spin waves in YIG is rather low because of its small saturation magnetization. For high-frequency magnonic devices, spin waves at higher frequencies are required. Here we demonstrate the efficient excitation of high-frequency exchange-dominated perpendicular standing spin waves (PSSWs) in nanometer-thick YIG films with a thin CoFeB capping layer. Using global microwave excitation fields, we measure intense PSSWs up to 10th order. We also observe strong hybridization between the PSSW modes in YIG and the FMR mode of CoFeB, causing characteristic anti-crossing behavior in the spin-wave spectra. We explain the excitation of PSSWs by a dynamic exchange torque at the YIG/CoFeB interface. The highly localized torque originates from exchange coupling between two forced magnetization oscillations of different amplitude in the YIG and CoFeB layers. As a consequence, spin waves are launched into both layers and a PSSW forms when the wave vector matches a confinement condition. No PSSWs are excited when the exchange coupling between YIG and CoFeB is suppressed by a nonmagnetic insertion layer.

MA 46.9 Thu 17:15 H 0110

Spin-wave transport in hexagonal nanotubes — Michael Zimmermann[1], Jorge Otálora[2], Sebastian Wintz[3], Elisabeth Josten[4], Tobias Schneider[4], Helmut Schultheiss[4], Jürgen Lindner[4], Christian Back[1], Jürgen Fassbender[4], and •Attila Kákay[4] — [1]Physics Department, University of Regensburg, 93040 Regensburg, Germany — [2]Leibniz Institute for Solid State and Materials Research Dresden (IFW Dresden), Institute for Metallic Materials, 01069 Dresden, Germany — [3]Paul Scherrer Institut, Villigen PSI, Switzerland — [4]Helmholtz-Zentrum Dresden - Rossendorf, Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany

Spin-wave propagation in ferromagnetic nanotubes is fundamentally different than in flat thin films as shown recently[1]. In particular, the dispersion relation is asymmetric regarding the sign of the wave vector. As a consequence, spin waves traveling in opposite directions have different wavelengths. This purely curvature induced effect originates from the dipole-dipole interaction. Such non-reciprocal spin-wave propagation[2] is known for flat thin films with interfacial Dzyalonshiinsky-Moriya interaction. In this work we investigate spin-wave transport in nanotubes with hexagonal cross section using micromagnetic simulations and Scanning Transmission X-ray Microscopy. In contrast to round tubes the hexagonal tubes provide more channels - reciprocal and non-reciprocal ones - for spin-wave transport. [1] J.A. Otálora, et. al., Phys. Rev. Lett. 117, 227203 (2016). [2] K. Zakeri, et. al., Phys. Rev. Lett. 104, 137203 (2010).

MA 46.10 Thu 17:30 H 0110

Phonon-pulse-induced magnetization dynamics in magnetic tunnel junctions — •Hangfu Yang, Xiukun Hu, Sibylle Sievers, Mark Bieler, and Hans W. Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig, Germany.

Manipulating the angular momentum of spins with external stimulus is a key issue in the field of spintronic with the aim to boost logic and memory applications. Here, we report time-domain measurements of magnetization dynamics in magnetic tunnel junctions (MTJs) driven by femtosecond-laser-induced phonon pulses through the inverse magnetostriction effect. The precession frequency is strongly dependent on amplitude and angle of the applied magnetic field. We find that the phonon-induced precession frequency differs from the precession frequency triggered by spin transfer torque. Most likely this is due to a spatially nonuniform precession mode excitation of the MTJ by the phonon pulses. Furthermore, we demonstrate coherent control of magnetization precession using two laser pulses at various magnetic fields and heating positions.

MA 46.11 Thu 17:45 H 0110

Controlling chiral domain walls in antiferromagnets using spin-wave helicity — •Alireza Qaiumzadeh, Lars Kristiansen, and Arne Brataas — Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

In antiferromagnets, the Dzyaloshinskii-Moriya interaction lifts the degeneracy of left- and right-circularly polarized spin waves. This relativistic coupling increases the efficiency of spin-wave induced domain-wall motion. In this talk, we report a fast all-magnonic helicity-dependent antiferromagnetic domain wall motion in the presence of the Dzyaloshinskii-Moriya interaction.

MA 47: Focus Session: Spinorbitronics – from efficient charge/spin conversion based on spin-orbit coupling to chiral magnetic skyrmions II (joint session MA/TT)

Time: Thursday 15:00–18:00 Location: H 1012

Invited Talk MA 47.1 Thu 15:00 H 1012
Spin orbit fields at the Fe/GaAs(001) interface — •Christian Back — Fakultät für Physik, Universität Regensburg — Physik-Department, TU München

Interfacial spin-orbit torques (SOTs) enable the manipulation of the magnetization through an in-plane charge current. Here, we study a particularly simple single crystalline interface, Fe/GaAs(001)[1], which we use to demonstrate various effects related to interfacial SOTs. We demonstrate crystalline anisotropic magneto-resistance showing C_{2v} symmetry [2], second we show anisotropic magneto-optic response [3]. Finally, we use ferromagnetic resonance based methods to investigate interfacial SOTs and report the observation of robust SOT occuring at a single crystalline Fe/GaAs (001) interface at room temperature [4]. We find that the magnitude of the interfacial SOT, caused by the reduced symmetry at the interface, is comparably strong as in ferromagnetic metal/non-magnetic metal systems. The large spin-orbit fields at the interface also enable the spin-to-charge current conversion at the interface, known as spin-galvanic effect [4]. The results suggest that single crystalline Fe/GaAs interfaces may enable efficient electrical magnetization manipulation.

[1] M. Gmitra et al., Phys. Rev. Lett. 111, 036603 (2013) [2] T. Hupfauer et al., Nat. Commun. 6, 7374 (2015) [3] M. Buchner et al., Phys. Rev. Lett. 117, 157202 (2016) [4] L. Chen et al. Nat. Commun. 7, 13802 (2016)

MA 47.2 Thu 15:30 H 1012
Spin-charge interconversion in single crystalline Bismuth films grown on Ge(111) — •minh tuan dau[1], carlo Zucchetti[2], federico bottegoni[2], céline vergnaud[1], thomas guillet[1], alain marty[1], cyrille beigné[1], andrea picone[2], alberto calloni[2], giovanni isella[2], franco ciccacci[2], pranab kumar das[3], jun fujii[3], ivana vobornik[3], marco finazzi[2], and matthieu jamet[1] — [1]INAC-Spintec, CEA/CNRS/Grenoble-INP and Université Grenoble Alpes, 38054 Grenoble, France — [2]LNESS-Dipartimento di Fisica, Politecnico di Milano, 20133 Milano, Italy — [3]CNR-IOM Laboratorio TASC, 34149 Trieste, Italy

In this study, we have grown a bismuth wedge (0-12 nm) on Ge(111) by molecular beam epitaxy. Using structural characterization (RHEED and x-ray diffraction), we found a critical thickness of ~ 4.5 nm below which Bi exhibits an allotropic pseudocubic phase. A careful angle-resolved and spin-resolved photoemission spectroscopy study using synchrotron radiation showed that the pseudocubic phase exhibits surface states with linear band dispersion and a characteristic helical spin texture. We have then investigated the spin-charge interconversion at these surface states using different techniques: magneto-optical Kerr effect to probe the spin Hall effect (SHE), inverse SHE using optical spin orientation in the Ge film beneath and finally spin pumping from a ferromagnetic layer grown on top of Bi separated by an Al spacer. We found a significant signature of the spin-charge interconversion in these surface states and a clear Bi-thickness dependence of the conversion signals.

MA 47.3 Thu 15:45 H 1012
Scattering of surface and interface states at skyrmionic quasi-particles interacting with defects. — •Imara L. Fernandes, Mohammed Bouhassoune, Stefan Blügel, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Magnetic skyrmions are promising candidates as bits of a future information technology. The precise manipulation and detection of such small magnetic nanostructures is a key ingredient for future applications in spintronics devices. Recently, we proposed the tunneling spin-mixing magnetoresistance (TXMR) to detect magnetic skyrmions by all-electrical means [1,2]. The TXMR effect originates from the non-alignment of magnetic moments and it is affected by the presence of spin-orbit interaction. We explore from a full *ab initio* approach the possibility of tuning the TXMR by inserting *3d* and *4d* transition metal defects at the vicinity of skyrmions generated in PdFe bilayer deposited on Ir(111). In the latter system, we identify surface and interface states leading to pronounced TXMR signals after scattering at skyrmionic quasi-particles. We extract the lifetimes of these confined states and draw conclusions concerning the impact of skyrmions and various atomic defects.

[1] D.M. Crum *et al.*, Nat. Commun. **6**, 8541 (2015).
[2] C. Hanneken *et al.*, Nat. Nanotech, **10**, 1039 (2015).
– Funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator grant 681405 - DYNASORE).

MA 47.4 Thu 16:00 H 1012
Orbital fingerprints of skyrmions in ferro- and antiferromagnets — •Manuel dos Santos Dias and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

X-rays are a very powerful tool for investigating the magnetic properties of materials. The magnetic circular dichroism in ferromagnets can be combined with sum rules to separate the net spin and orbital magnetic moments, while compensated antiferromagnets have no circular dichroism. In this contribution, we explain why skyrmions in ferromagnets encode topological information in their orbital magnetic moment, that can in principle be extracted via sum-rule analysis [1]. This part of the orbital moment originates from magnetic noncoplanarity, as found in our original work and in a simple model description [2]. We then extend the analysis to a skyrmion lattice in an antiferromagnetic background. We investigate whether the topological orbital signature is present, and whether circular dichroism exists and can detect topological information.

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

[1] M. dos Santos Dias *et al.*, Nat. Commun. **7**, 13613 (2016)
[2] M. dos Santos Dias and S. Lounis, Proc. SPIE **10357**, Spintronics X, 103572A (2017)

15 minutes break

MA 47.5 Thu 16:30 H 1012
Large perpendicular magnetic anisotropy and Dzyaloshinskii Moriya chiral interaction at room temperature in epitaxial graphene-based structures — Fernando Ajejas[1], Adrian Gudin[1], Ruben Guerrero[1], Leticia De Melo Costa[1], Jose Manuel Diez[1], Pablo Olleros[1], Alberto Anadon[1], Maria Varela[2], Manuel Valvidares[3], Pierluigi Gargiani[3], Jan Vogel[4], Stefania Pizzini[4], Julio Camarero[1], Rodolfo Miranda[1], and •Paolo Perna[1] — [1]IMDEA Nanociencia, Madrid, Spain — [2]ALBA SYNCHROTRON, Barcelona, Spain — [3]Universidad Complutense de Madrid, Madrid, Spain — [4]CNRS Institut Néel, Grenoble, France

A major challenge for future spintronics is to develop suitable spin transport channels with superior properties as long spin lifetime and propagation length. Graphene can meet these requirements, even at room temperature. On the other side, the use of fast motion of Néel-type chiral domain walls (and magnetic skyrmions) can satisfy the demands for high-density data storage, low power consumption and high processing speed. Here, by engineering the epitaxial growth of gr/Co/Pt(111) stacks on (111)-oriented oxide crystals, we achieve an enhanced perpendicular magnetic anisotropy (PMA), with Co thickness up to 4 nm, and left-handed Néel-type chiral domain walls (DWs) stabilized by a strong effective Dzyaloshinskii Moriya interaction (DMI).

MA 47.6 Thu 16:45 H 1012
Analysis of the Dzyaloshinskii-Moriya interaction and spin-orbit torques in Co-based trilayers — •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

Originating from the interplay of spin-orbit coupling and broken inversion symmetry, the Dzyaloshinskii-Moriya interaction (DMI) attracts ever-growing attention as it mediates the formation of chiral spin textures such as magnetic skyrmions. To predict the magnitude of this chiral interaction from *ab initio*, typically, one adopts either demanding computational frameworks or limiting approximations for the spin-orbit interaction. In contrast, we present an advanced Wannier interpolation scheme that evaluates DMI in its modern theory [1] based on the ferromagnetic ground state including spin-orbit coupling self-consistently. Utilizing this technique, we identify the microscopic origin of DMI and spin-orbit torques in the trilayers Ir_xPt_{1-x}/Co/Pt and Au_xPt_{1-x}/Co/Pt [2]. Tuning the composition x, we find that DMI changes sign, promoting the respective systems as promising candidates for detailed experimental studies. We examine also the consequences of the obtained anisotropy of the spin-orbit torques with the magnetization direction for the dynamical properties of skyrmions.

Funding from the DFG (Grant No. MO 1731/5-1) and from the EU Horizon 2020 via the FET-Open project MAGicSky is acknowledged.

[1] F. Freimuth *et al.*, J. Phys. Condens. Matter **26**, 104202 (2014).
[2] J.-P. Hanke *et al.*, arXiv:1711.02657.

MA 47.7 Thu 17:00 H 1012

Electrically and thermally-induced spin polarization in semiconductor heterostructures and at perovskite oxides interfaces — •Anna Dyrdał[1,2], Łukasz Karwacki[3], Józef Barnaś[2,3], Vitalii Dugaev[4], and Jamal Berakdar[1] — [1]Institut für Physik, Martin-Luther Universität Halle-Wittenberg, Halle, Germany — [2]Faculty of Physics, A. Mickiewicz University, Poznan, Poland — [3]Institute of Molecular Physics, Polish Academy of Sciences, Poznan, Poland — [4]Department of Physics and Medical Engineering, Rzeszow University of Technology, Rzeszow, Poland

Spin-orbit interaction leads to a variety of spin and transport phenomena that enable control of single spins in a pure electrical manner. The physics that stands behind such effects is very rich and depends on the nature of spin-orbit coupling in the host material. We will discuss and summarize our recent results on electrically and thermally induced nonequilibrium spin polarization obtained within effective models describing 2DEG in semiconductor heterostructures and perovskite oxide interfaces [1-3]. In principle, we will focus on analytical and numerical results describing temperature dependences and show that impurities vertex correction plays important role in thermally-induced spin polarization. We will comment relations between spin polarization and Berry curvature. The influence of spin-orbit torque induced due to non-equilibrium spin-polarization in magnetic systems on spin dynamics will be also discussed.

[1] A. Dyrdał, et al., arXiv:1711.07707; [2] Ł. Karwacki, et al., arXiv:1711.07702; [3] A. Dyrdał, et al., PRB 95, 245302 (2017).

MA 47.8 Thu 17:15 H 1012

Engineering Chiral and Topological Orbital Magnetism of Domain Walls and Skyrmions
— •Fabian R. Lux, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov —
Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

In the field of spin-orbitronics, the orbital physics of electrons plays a central role, with the orbital magnetization representing a key concept. While the orbital magnetism in ferromagnets is relatively well understood, very little is known about it for non-collinear structures such as magnetic skyrmions and domain walls. By employing a semiclassical Green's function formalism, we demonstrate how the orbital magnetization in extended chiral magnetic systems can be understood as the electronic response to emergent electromagnetic fields [1]. We discovered that in such systems the spin-orbit interaction can be used to a great advantage in that it promotes a complex interplay of real-space and k-space topology leading to enhanced orbital responses in interfacial chiral magnets. Besides discussing possible applications of the emergent orbital magnetism in chiral spin systems we also suggest new perspectives for the field of chiral orbitronics.

[1] F. R. Lux *et al.*, arXiv:1706.06068 (2017)

MA 47.9 Thu 17:30 H 1012

Current-induced remagnetization in epitaxial Au/Fe/MgO(001) heterostructures — •Pika Gospodaric[1], Ewa Mlynczak[1], Daniel E. Bürgler[1], Lukasz Plucinski[1], Yuriy Mokrousov[2], and Claus M. Schneider[1] — [1]Peter Grünberg Institut PGI-6, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

In the emerging field of the spintronics devices the focus shifts towards the three-terminal cell structure. In this geometry, the magnetization of the recording magnetic layer is switched with an in-plane electric current. Presently, the spin-orbit torque is considered as one of the most promising ways of current-induced switching of ferromagnets and antiferromagnets. Here, we study an epitaxial Fe(001) ultra-thin film, with in-plane remanent magnetization, sandwiched between the MgO substrate and an epitaxal Au thin film. This system has well-defined interfaces between the layers and a good crystalline quality, which gives rise to the typical four-fold in-plane magneto-crystalline anisotropy of Fe(001) layers. In a Hall bar geometry we observed reproducible switching of the magnetization of the Fe(001) thin film after applying a current density beyond $2 \cdot 10^7$ A/cm^2. The magnetic state was read-out by measuring the planar Hall voltage in the transversal channel. By varying the current density we were able to induce intermediate magnetization states, which could be explained with changes in the magnetic domain structure. These results give the prospect to apply Fe/Au heterostructures in neuromorphic architectures.

MA 47.10 Thu 17:45 H 1012

Dynamics of interacting Skyrmions in densely populated Skyrmion lattices — •Martin Stier and Michael Thorwart — University of Hamburg, Hamburg, Germany

We address issues which may arise in densely populated Skyrmion lattices which are possibly used in future high-capacity memory devices. A manipulation of the information-carrying Skyrmions is typically achieved by electrical currents - either in terms of spin-transfer or spin-orbit torques. However, Skyrmions themselves distort these torques in their surrounding area. This can actually result in the creation of new Skyrmions under certain conditions. Furthermore, an interaction between Skyrmions in different layers, e.g. in an artificial antiferromagnet, will change the dynamics of the according Skyrmions. This can even have beneficial effects, such as the prevention of the drift due to the Skyrmion Hall effect and an increase of the velocity.

MA 48: Quantum Coherence and Quantum Information Systems (joint session TT/MA)

Time: Thursday 15:00–17:00 Location: H 2053

Invited Talk MA 48.1 Thu 15:00 H 2053

Non-Markovian Quantum Thermodynamics: Second Law and Fluctuation Theorems — •Robert S Whitney — Laboratoire de Physique et Modélisation des Milieux Condensés, Université Grenoble Alpes & CNRS, 25 avenue des Martyrs, BP166 38042 Grenoble, France

The thermodynamics of quantum systems which are strongly coupled to reservoirs is fraught with difficulties, such as non-factorizable initial conditions and non-Markovian system dynamics. However, there is huge practical interest in machines (heat engines, refrigerators, etc) in this strong coupling regime, because weak-coupling implies very small currents, and hence very small power outputs.

This work shows that a real-time diagrammatic technique is an equivalent of stochastic thermodynamics for strongly-coupled non-Markovian quantum machines. Symmetries are found between quantum trajectories and their time-reverses on the Keldysh contour, for any interacting quantum system coupled to ideal reservoirs of electrons, phonons or photons. These lead to quantum fluctuation theorems the same as the well-known classical ones (Jarzynski and Crooks equalities, non-equilibrium partition identity, etc), whether the system's dynamics are Markovian or not. Some of these also hold for non-factorized initial states. We identify a family of approximations, suitable for concrete calculations of a machine's power and efficiency, which respect the symmetries that ensure fluctuation theorems. In all cases, including non-factorized initial states, the second law of thermodynamics is proven to hold on average, with fluctuations violating it.

[1] arXiv:1611.00670

MA 48.2 Thu 15:30 H 2053

Nuclear spin decay in semiconductor quantum dots — •Nina Fröhling[1], Mikhail M. Glazov[2], and Frithjof B. Anders[1] — [1]Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44227 Dortmund — [2]A. F. Ioffe Physico-Technical Institute, 26 Politechnicheskaya, 194021 St. Petersburg, Russia

We study bath spin auto-correlation functions of nuclear spin decay in an isolated semi-conductor quantum dot doped with an electron or an electron hole as described by the central spin model. The electronic central spin is coupled to a bath of nuclear spins via hyperfine interaction, which dominates the short time regime. We study the analytical solution of the nuclear spin decay with homogeneous hyperfine coupling, as well as other limiting cases. Furthermore, we describe the nuclear spin correlation fully quantum mechanically for up to N = 18 bath spins through time evolution via the Lanczos method and discuss the influence of quadrupolar interaction and nuclear Zeeman splitting on nuclear spin decay.

MA 48.3 Thu 15:45 H 2053

Magnetic field dependency of the electron spin revival amplitude in periodically pulsed quantum dots — •Iris Kleinjohann and Frithjof Anders — Lehrstuhl für Theoretische Physik II, Technische Universität Dortmund, 44227 Dortmund

When pump-probe experiments are performed on singly charged quantum dots, the spin dynamics synchronizes with the periodic pump pulses. In experiments an external magnetic field is applied in Voigt geometry and the synchronization of spin dynamics can be observed in the electron spin polarization along the optical axis. After a pump pulse the electron spin polarization shows a complete dephasing due to the hyperfine interaction. Directly before the impact of the next pump pulse a revival of polarization occurs indicating synchronization. We describe the spin dynamics in a periodically pulsed quantum dot within the central spin model. The time evolution is calculated by a Lindblad approach and shows a revival of electron spin polarization as well as an alignment of nuclear spins. The resonance condition favors an integer or a half-integer number of electron Larmor precession over one pulse interval. The non-monotonic revival amplitude as function of the external magnetic field is related to the nuclear Zeeman term.

MA 48.4 Thu 16:00 H 2053

Semiclassical simulation of weakly coupled semiconductor quantum dots — •Andreas Fischer and Frithjof Anders — Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44227 Dortmund

In two-color pump-probe experiments one can excite distinct subsets of singly charged quantum dots independently by laser pulses of different photon energies. The optically oriented electron spins precess in an external magnetic field applied in Voigt geometry. Phase shifts, changing dephasing times and amplitude modulations in the signal depending on the pump configuration indicate a coherent interaction between the quantum dots. The experimental signatures can be reproduced by comprising two central spin models augmented by a Heisenberg interaction between the two central spins. The time evolution is calculated using a semiclassical approximation (SCA). To include the trion state excited by the pump pulses and the subsequent decay we combine the SCA with the quantum mechanical Lindblad equation. Our approach can be extended to multi-color pump-probe experiments.

MA 48.5 Thu 16:15 H 2053

Mode locking in a periodically pulsed quantum dot — •Natalie Jäschke and Frithjof Anders — Technische Universität Dortmund, Lehrstuhl für Theoretische Physik II, 44227 Dortmund

In pump-probe experiments single electron charged semiconductor quantum dots are subjected to periodic optical excitation generating electron and nuclear spin polarization. In the short time regime the decoherence of the electron spin polarization is governed by the hyperfine interaction with the nuclear spins. We present a theory that combines the effect of the periodic laser pump pulses and the nuclear spin bath on the electron spin polarization.

While we treat the laser pumping quantum-mechanically, a classical simulation of the Overhauser field bridges the time between two laser pulses. We analyze the time dependence of the electron spin dynamics as well as the electron spin noise spectrum. Data for the non-equilibrium steady state spectral distributions of the Overhauser field are presented for the long time limit. Using a steady state Floquet condition the peak locations of the Overhauser field distribution parallel to the external magnetic field can be derived.

MA 48.6 Thu 16:30 H 2053

Holographic Flow Equation Calculation of Entanglement Entropies of Spin Chains — •Hannes Coners and Stefan Kehrein — University of Göttingen

The Holographic Flow Equation Approach was introduced in arxiv/1703.03925 and provides a new method for quantifying entanglement of quantum many-body systems. In this talk the method will be motivated and results for different spin chains (XY, XX and Ising model) are shown. These spin chains consist of two subsystems which are coupled by a weak link (coupling strength g). To benchmark the method, different sizes of the subsystems as well as different values of g are considered.

MA 48.7 Thu 16:45 H 2053

Quantum spin systems at the edge of a quantum memory — •Yevheniia Cheipesh, Lorenzo Cevolani, and Stefan Kehrein — University of Göttingen

We consider the Kitaev Toric Code with open boundary conditions. This system has a highly degenerate ground state that lives on the boundary and can be described as a one dimensional system. The ground state is derived explicitly and its dimension scales exponentially with the size of the system. Based on this, the entanglement properties of the model are studied for two types of bipartition: the first, where the subsystem A is completely contained in B; and the second, where the boundary of the system is shared between A and B. In the former case the entanglement entropy is the same as for periodic boundary conditions, which means that the bulk is completely decoupled from the boundary on distances larger than the correlation length. In the latter, deviations from the torus configuration appear due to the edge states, and lead to the increase of the entropy. We also derive the dispersion relation of the boundary theory under the perturbation with an external magnetic field along the x-direction.

MA 49: Terahertz dynamics

Time: Thursday 15:00–16:30 Location: EB 202

MA 49.1 Thu 15:00 EB 202

Exploring magneto-optical interactions in rare-earth doped garnets by multi-dimensional THz spectroscopy — •Shovon Pal[1], Christian Tzschaschel[1], Takuya Satoh[2], and Manfred Fiebig[1] — [1]ETH Zurich, Switzerland. — [2]Kyushu University, Japan.

Multi-dimensional nonlinear spectroscopy is a very powerful tool that bears the potential to unravel the dynamics (both coherent and incoherent) and coupling of elementary interactions in solid-state systems. Due to low THz photon energies, these radiations provide a means to address electronic states by resonant excitation and detection of electronic states having energy differences in the meV range. Typically, intense THz pulses have the potential to induce ultrafast electric- or magnetic-switching operations that last from a few tens of femtoseconds to a few tens of picoseconds. For example, observation of multiple harmonics and quantum coherences in semiconductor systems and canted antiferromagnets. Further, both energy and time scales of THz radiation favors fundamental investigations on magneto-optical interplay at the quantum level. Garnets, in particular, provide a platform towards the development of technologically relevant material for magneto-optical spintronic devices. On doping with rare-earth elements, they show an unusual strong excitation of magnetization precession with a frequency in the THz regime, resulting from the exchange interaction between rare-earth and transition metal elements. We present our direct observation of this nonlinear magneto-optical interaction at 0.5 THz in a Gd, Yb-doped bismuth iron garnet via two-dimensional THz time domain spectroscopy.

MA 49.2 Thu 15:15 EB 202

Antiferromagnetic resonance in Mn2Au driven by Néel spin

orbit torque — •Nilabha Bhattacharjee, Stanislav Bodnar, Alexey Sapozhnik, Olena Gomonay, Martin Jourdan, and Jure Demsar — Johannes Gutenberg University, Mainz, 55099, Germany

Ultrafast spin dynamics in antiferromagnetic (AFM) materials has become a topic of immense interest due to its possible potential applications in spintronics. The AFM material Mn2Au, which is of huge prospect due to its high Néel temperature (~1600K) [1], strong spin-orbit coupling and high conductivity, requires a better understanding of its microscopic properties.

A comprehensive study of complex optical conductivity in thin c-axis grown Mn2Au films is presented in this work by means of time-domain THz spectroscopy.Thin (40 nm) Mn2Au films are grown by rf- sputtering on a 8 nm thick Ta buffer layer, deposited on a 500 micron thick R-cut sapphire substrate [2]. A damped antiferromagnetic resonance (AFMR) mode at 1THz (at room temperature) is observed in the conductivity data of Mn2Au by fitting with Drude-Lorentz model. A systematic study of temperature dependence of AFMR is been performed and a shift of the AFMR towards lower frequency is observed as the temperature varies from 5K to 450K. Here we also propose Néel spin orbit torque [3] driven mechanism of the in-plane AFMR mode in Mn2Au.

[1] S Khmelevskyi et al., App. Phys. Lett., 93, 162503 (2008). [2] M Jourdan et al., J. Phys. D: Appl. Phys., 48, 385001 (2015). [3] J. Železný et al., Phys. Rev. Lett. 113, 157201 (2014).

MA 49.3 Thu 15:30 EB 202

Narrow-band THz spin dynamics in ferromagnetic metallic thin films — •Stefano Bonetti — Stockholm University, 10691 Stockholm, Sweden

The interaction between magnetism and light is receiving considerable interest in recent years, after the groundbreaking experiments that showed that ultrashort (∼100 fs) infrared light pulses can be used to demagnetise or even switch the magnetisation of thin film ferromagnets. However, to date no clear and commonly accepted understanding of the fundamental physical processes governing the ultrafast magnetization has been reached., partly because accurate modelling of the infrared fs laser-induced highly non-equilibrium state remains a key obstacle.

In this talk, I will present recent experiments where we used strong THz fields, rather than infrared pulses, to excite ultrafast magnetisation dynamics in thin film ferromagnets, and probed it with the time-resolved magneto-optical Kerr effect. We used narrow-band THz pulses produced at the High-Field High-Repetition-Rate Terahertz facility @ ELBE (TELBE) to drive magnetisation dynamics in an amorphous CoFeB sample. Our results show that demagnetisation is strongly dependent on the frequency of the THz pulses and that there is a competition with frequency dependent re-magnetising effects, and that the number and type of defects affect the process. Our measurements illustrate the relation between charge- and spin-dependent scattering of conduction electrons, deepening our understanding of ultrafast spin dynamics.

MA 49.4 Thu 15:45 EB 202

Optical generation of femtosecond spin-current pulses in metallic multilayers: optimizing the efficiency — •Alexey Melnikov[1,2], Liane Brandt[1], Mirko Ribow[1], Niklas Liebing[1], Ilya Razdolski[2], and Georg Woltersdorf[1] — [1]Martin Luther University Halle-Wittenberg, Institute of Physics — [2]Fritz Haber Institute of the Max Planck Society, Department of Physical Chemistry

The key challenge in a rapidly emerging field of modern spintronics consists in the push from the GHz to THz domain. In particular, it requires the development of techniques for the generation of femtosecond spin current (SC) pulses. With the help of magneto-induced second harmonic generation (mSHG) in the back pump-front probe scheme, we have demonstrated long-range spin transport on a femtosecond timescale upon laser excitation of the Fe film in epitaxial Fe/Au bilayers [1]. Later on, in Fe/Au/Fe tri-layers, this technique allowed us to demonstrate 250 fs-short SC pulses and attribute their origin to the non-thermal spin-dependent Seebeck effect at ferromagnet/normal metal interfaces [2]. Here, using both mSHG and magneto-optical Kerr effect detection in similar structures with variable thickness of the Fe emitter, we optimize the excitation of THz standing spin waves [3] and obtain new insights into the underlying electron and spin dynamics. In particular, from the SC generation efficiency dependence on the emitter thickness peaking at 4 nm, we estimate the escape depth of hot majority electrons in Fe of about 2 nm. [1] A. Melnikov et al., PRL 107, 076601 (2011); [2] A. Alekhin et al., PRL 119, 017202 (2017); [3] I. Razdolski et al., Nature Commun. 8, 15007 (2017).

MA 49.5 Thu 16:00 EB 202

Terahertz laser-induced spin waves in metallic multilayers: tuning the frequencies — •Liane Brandt[1], Mirko Ribow[1], Niklas Liebing[1], Ilya Razdolski[2], Georg Woltersdorf[1], and Alexey Melnikov[1,2] — [1]Martin Luther University Halle-Wittenberg, Institute of Physics — [2]Fritz Haber Institute of the Max Planck Society, Department of Physical Chemistry

Recently, in Fe/Au/Fe tri-layers we have demonstrated the excitation of sub-THz perpendicular standing spin waves (PSSW) in the 14 nm-thick Fe layer studied by the time-resolved magneto-optical Kerr effect in a back pump-front probe scheme [1]. This high-frequency spin dynamic is driven by interface-confined spin transfer torque (STT) exerted by 250 fs-short spin current pulses generated in the optically excited opposite Fe layer [2]. To tune the PSSW frequencies, we fabricated an epitaxial Fe/Au/Fe structure with continuously varying Fe collector thickness from 1 to 17 nm. We demonstrate efficient STT-driven excitation of PSSWs with frequencies up to 2 THz corresponding to spin-wavelengths of 2 nm. Signatures of the higher-order PSSWs with even higher frequencies (up to 5 THz) are also observed. We analyze the PSSW dispersion, damping, and amplitudes in the time domain as well as their dependence on the collector thickness and discuss new insights into the STT-induced THz spin dynamics.

[1] I. Razdolski et al., Nature Commun. 8, 15007 (2017)
[2] A. Alekhin et al., PRL 119, 017202 (2017)

MA 49.6 Thu 16:15 EB 202

Influence of the electron scattering lifetime onto THz-spintronic experiments — Laura Scheuer[1], Sascha Keller[1], Garik Torosyan[2], Marco Battiato[3], René Beigang[1,2], and •Evangelos Th. Papaioannou[1] — [1]Department of Physics and Research Center Optimas, TU Kaiserslautern, Kaiserslautern, 67663, Germany — [2]Photonic Center Kaiserslautern, Kaiserslautern, 67663, Germany — [3]School of Physical and Mathematical Sciences, Nanyang Technological University, 21 Nanyang Link, Singapore 637371, Singapore

We show how the THz-E-field amplitude and the bandwidth of the THz radiation, generated by spintronic Fe/Pt bilayer emitters [1], can be optimized by the crystal structure of Pt. By changing the growth parameters, Pt can grow along different crystallographic directions resulting in different degrees of epitaxy on top of Fe. Accordingly, the electron-phonon/defect scattering lifetime at the Fe/Pt interface is modified which influences directly the emitted THz spectrum. We present a theoretical model which correlates the loss of energy of the hot electrons, with the ISHE current that causes the THz emission. By taking into account the response function of the THz detector we describe the influence of the crystal structure of Pt onto the THz signal shape and spectrum. We compare our calculations with experimental data obtained from sample series of Fe(2-12nm)/Pt(2-6 nm).

[1]G. Torosyan et al., arxiv.org/abs/1707.08894 (2017)

MA 50: Soft and hard permanent magnets

Time: Thursday 15:00–16:45 Location: EB 301

MA 50.1 Thu 15:00 EB 301

Improving magnetic properties of Ce-Fe permanent magnets with La doping — •Martin Hoffmann[1,2], Munehisa Matsumoto[2], Takashi Miyake[3], and Hisazumi Akai[2] — [1]Institute for Theoretical Physics, Johannes Kepler University Linz, Austria — [2]Institute for Solid State Physics, University of Tokyo, Japan — [3]National Institute of Advanced Industrial Science and Technology (AIST), Tsukuba, Japan

Powerful permanent magnets are a crucial component in electric motors and gen- erators, while the most powerful magnets available nowadays are alloys of rare-earth (RE) elements and magnetic transition metal elements. Unfortunately, the availability of the RE elements of the best magnets is strongly limited. Therefore, different paths are undertaken in order to find better or cheaper permanent magnets. We study theoretically the effect of La and Co doping on the magnetic properties of potentially cheaper Ce-Fe permanent magnets with 1-2, 1-5, or 1-12 composition.

We studied the magnetic moments, coupling, anisotropy and the Curie temperature. These quantities and their dependence on the doping have to be at first better understood and in a second step optimized for a good performance of the magnets. We found significant changes in the calculated magnetic properties when mixing Ce with La and Fe with Co. Looking at the formation energy of the compounds identifies possible stable concentration regimes where new compounds could be synthesized.

MA 50.2 Thu 15:15 EB 301

Hard magnetic Fe-Hf-Sb based intermetallic compound of hexagonal Laves phase structure — •Dagmar Goll, Thomas Gross, Ralf Loeffler, Ulrich Pflanz, Tim Vogel, Andreas Kopp, Tvrtko Grubesa, and Gerhard Schneider — Aalen University, Materials Research Institute (IMFAA), Aalen, Germany

Rare earth free phases are searched for possible candidates for novel hard magnets to realize efficient energy converters. By experimental bulk high-throughput screening the ternary system Fe-Hf-Sb, off-stoichiometric $(Fe,Sb)_{2+x}Hf_{1-x}$ with a composition of Fe60.0-Hf26.5Sb13.5 with potential as hard magnetic phase has been discovered. By quantitative domain structure analysis, interesting intrinsic magnetic properties of $J_s \approx 1$ T and $K_1 \approx 1.5$ MJ/m^3 are estimated at room temperature. By magnetometry, bulk intrinisic properties of $J_s \approx 0.7$ T and $K_1 \approx 1.4$ MJ/m^3 are found from the approach to ferromagnetic saturation. X-ray diffraction analysis proves the presence of hexagonal C14 Laves phase structure. Alloying elements like Co or Mn can modify the crystal structure and ferromagnetic behavior. In addition, rapid quenching is applied to realize nanocrystalline magnetic materials thereof. The project is supported by Ministry of Economic Affairs, Labor and Housing Baden-Wuerttemberg.

MA 50.3 Thu 15:30 EB 301

$Li[Li_{1-x}Co_x]AE_2N_2$ (AE = Ca, Sr): New examples for magnetically anisotropic transition metals in linear coordination — •Tanita J. Ballé[1], Peter Höhn[2], and Anton Jesche[1] — [1]EP VI, Center for Electronic Correlations and Magnetism, Augsburg University, 86159 Augsburg, Germany — [2]Max-Plack-Institut für Chemische Physik fester Stoffe, Nöthnitzer Str. 40, 01187 Dresden, Germany

$Li_2[Li_{1-x}Fe_x]N$ is one of the scarce rare-earth free hard magnets and shows a huge magnetic anisotropy and the highest known coercivity field of more than 11 T! These properties are attributed to the unquenched orbital moment of iron, enabled by the perfect linear, twofold coordination of iron between nitrogen [1]. In order to investigate the necessity as well as sufficiency of this geometrical motive, we studied similar compounds [2]. We will show that large coercivity fields are not restricted to iron. Isothermal and temperature dependent magnetic measurements were performed on $Li[Li_{1-x}Co_x]AE_2N_2$, which contains cobalt in linear coordination. Ferromagentic ground states with a coercivity of ~ 0.5 T are observed at 2 K. The Hysteresis vanishes at 76 K for AE = Ca and 43 K for AE = Sr, respectively, and is clearly reflected in the temperature dependence of the magnetization. We conclude that the structural motive of a transition metal in linear coordination with only two neighbours, allows to predict materials with stable magnetic properties. [1] A. Jesche *et al.* Nat. Commun. **5**:3333. doi: 10.1038/ncomms4333 (2014) [2] P. Höhn, TJB *et al.* Inorganics 4, **42** (2016)

MA 50.4 Thu 15:45 EB 301

Magnetic properties of iron based 1:12 permanent magnets from first principles — •Olga Yu. Vekilova, Olle Eriksson, and Heike C. Herper — Department of Physics and Astronomy, Uppsala University, Uppsala, Sweden

The iron-rich compounds are very promising for permanent magnet applications because of their large magnetic moments, rather high coercivity and sufficiently high Curie temperature. The 1:12 compounds with the $ThMn_{12}$-type structure are among the best candidates. However, light rare earths and iron cannot be stabilized in a binary 1:12 compound without a third dopant, like Ti or V. Such substitution results in a significant decrease in the saturation magnetization of the compound and can also influence magnetocrystalline anisotropy and Curie temperature. We addressed the problem from first principles. Starting from the known stable $NiFe_{11}Ti$ and $SmFe_{10}V_2$ phases we tried to improve the magnetic properties by reducing the content of Ti and V respectively. The phase stabilities of $NdFe_{11-x}Ti_x$ and $SmFe_{10-x}V_x$ were calculated and compared to the available experimental data. We further substituted Nd in $NdFe_{11-x}Ti_x$, partially by Y, which is a light 4d element, and revealed how the content of Nd and Ti can improve the magnetocrystalline anisotropy.

MA 50.5 Thu 16:00 EB 301

Noncollinear magnetism in Mn_3X (X=Sn, Ge, Ga) compounds — •Bendegúz Nyári, András Deák, and László Szunyogh — Budapest University of Technology and Economics, Budapest, Hungary

The intermetallic compounds Mn_3X (X=Sn, Ge, Ga) in hexagonal crystal structure show complex magnetic behaviour. Neutron diffraction [1] and theoretical [2] studies reveal that these compounds have a triangular spin configuration displaying weak ferromagnetic deformation. In a recent theoretical work [3] nonplanar spin-configurations were also reported. In this work we investigate theoretically the formation of non-collinear spin configurations. Spin-model parameters were obtained from a spin-cluster expansion (SCE) technique and by fitting rotational energies to analytic expressions derived from group-theoretical arguments. A model based on six magnetic sublattices confirms indeed a planar weak ferromagnetic ground state. In case of Mn_3Ge, the investigation of the static spin-susceptibilty, $\chi(\mathbf{q})$, indicates, however, that the system can be stabilized in a complicated magnetic structure at finite wavevector $\mathbf{q}$. By using tensorial spin-interactions obtained from SCE, Monte-Carlo simulations are performed to study such complex magnetic ground states.

[1] S. Tomiyoshi et al., J. Magn. Magn. Mater. 54–57, 1001 (1986)
[2] L. M. Sandratskii and J. Kübler, Phys. Rev. Lett. 76, 4963 (1996)
[3] J. Kübler and C. Felser, Europhysics Lett. 108, 67001 (2014)

MA 50.6 Thu 16:15 EB 301

Using FORC to understand the microstructure-micromagnetism relationship in supermagnets — •Sven Erik Ilse, Felix Gross, Joachim Gräfe, and Eberhard Goering — Max Planck Institute for Intelligent Systems, Germany

First-order-reversal-curve (FORC) diagrams yield a great variety of magnetic information such as coercive and interaction field distributions. We have recently demonstrated that FORC on MnBi can provide deep insight in the relationship between magnetism and microstructural properties, as grain size distributions and grain shapes[1]. Following these studies we investigated neodymium based permanent magnets and their FORC density relationship to microstructural properties. We systematically manipulated the microstructure of the samples by consecutive annealing (at different temperatures and intervals), and correlated their grain size-distributions with FORC diagrams. Our analysis of the grain size distributions showed that the grain sizes shift to higher diameters and the distribution broadens for longer annealing times. The room temperature FORC diagrams revealed that the width of the coercive field distribution increases. Correlating the widths of grain size- and coercive field- distributions reveals a linear dependence, which enables us to draw conclusions about grain sizes directly from FORC measurements. Our results demonstrate the ver-

satility of FORC investigations providing rich additional information and enabling detailed understanding of coercive and interaction field distributions of our samples related to microstructure and grain size distributions.

[1] S. Muralidhar, et al., Physical Review B 95.2 (2017): 024413.

MA 50.7 Thu 16:30 EB 301

Anisotropic Effects of the Grain Boundary Diffusion Process (GBDP) in Textured Nd Fe B Magnets — •Tim Helbig, Andreas Abel, Simon Sawatzki, and Oliver Gutfleisch — TU Darmstadt

The Grain Boundary Diffusion Process (GBDP) is an industrially applied process to increase the coercivity of Nd-Fe-B sintered magnets using a minimal amount of heavy rare earth elements (HRE). In this process, the fully sintered and textured magnets are coated with a HRE or HRE compound and exposed to a heat treatment, causing the HRE to diffuse into the magnet. In order to investigate the texture dependence of this diffusion, a single face of a brick shaped sample was covered with Dy or Dy alloy and heat treated. Subsequently a coercivity profile was determined, by cutting the sample into small slices and measuring their coercivity individually. Simultaneously a second coercivity profile was derived by measuring the coercivity of the remaining sample piece after cutting each respective slice. The two data sets were compared allowing not only conclusions regarding the anisotropic grain boundary diffusion of Dy or Dy alloy, but also showed a pole surface hardening effect. This means that the compact magnet showed a higher coercivity than the average of its parts. Energy Dispersive X-ray spectroscopy (EDX) was used to relate the anisotropic diffusion of Dy to the obtained coercivity profile.

Financial support by the German federal state of Hessen through its LOEWE program "RESPONSE" is gratefully acknowledged.

MA 51: Magnetic textures II

Time: Thursday 15:00–17:30 Location: EB 407

MA 51.1 Thu 15:00 EB 407

Chiral Magnetic Phase Diagrams and Cubic Anisotropy — •Lukas Heinen[1], Alfonso Chacón Roldán[2], Marco Halder[2], Andreas Bauer[2], Wolfgang Simeth[2], Sebastian Mühlbauer[2], Halmuth Berger[3], Markus Garst[4], Christian Pfleiderer[2], and Achim Rosch[1] — [1]Universität zu Köln, Germany — [2]Technische Universität München, Germany — [3]École Polytechnique Federale de Lausanne, Switzerland — [4]Universität Dresden, Germany

Chiral magnets exhibit rich magnetic phase diagrams, including several types of chiral magnetic order. The most prominent of these phases is the skyrmion lattice phase, consisting of a regular arrangement of whirl-like magnetic structures called skyrmions. Since skyrmions benefit from topologically-induced protection, and are easily manipulated, they are promising candidates for future applications in spintronics. Consequently, their range of thermodynamic stability is the topic of intensive research. However, the phase diagrams for unstrained bulk systems reported so far are remarkably similar across a multitude of different materials.

Motivated by recent experiments we study the influence of certain types of *cubic* anisotropy. The resulting phase diagram matches the experiment, is highly anisotropic and contains two new phases, one of which is a *second* skyrmion lattice phase.

MA 51.2 Thu 15:15 EB 407

Creating 3D-magnetic textures in synthetic antiferromagnets by focused ion beam irradiation — •Fabian Samad[1], Leopold Koch[1,2], Phani Arekapudi[1], Miriam Lenz[2], and Olav Hellwig[1,2] — [1]Institute of Physics, Chemnitz University of Technology, Germany — [2]Institute for Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Germany

The DMI assisted emergence of 3D-magnetic textures in general and magnetic skyrmions in particular were hitherto typically observed in B20-materials at low temperatures or in ferromagnetic multilayers at room temperature [1]. In contrast, we used a synthetic antiferromagnet (AF) [2] as a ground system which provides the striking benefits of an absence of stray fields as well as high domain wall velocities [3], making it interesting for possible future data storage applications. Using focused ion beam irradiation with different fluences, we modified the local energy interplay between AF interlayer exchange and dipolar energy. Thus, we were able to create a variety of laterally coexisting magnetic phases and 3D-magnetic textures in different confinements. Detailed investigation of their interactions as well as their field reversal behavior were performed with in-field high resolution magnetic force microscopy.

[1] Soumyanarayanan et al., Nat. Mater. 16, 898-904 (2017)
[2] Hellwig et al., J. Magn. Magn. Mater. 319, 13-55 (2007).
[3] Yang et al., Nat. Nanotechnol. 10, 221-226 (2015).

MA 51.3 Thu 15:30 EB 407

Reciprocal-space structure of the magnetic modulations in lacunar spinel $GaMo_4S_8$ studied by SANS — •Ádám Butykai[1,2], Sándor Bordács[1,2], László Ferenc Kiss[3], László Balogh[1], Lisa DeBeer-Schmitt[4], and István Kézsmárki[1,2,5] — [1]Department of Physics, Budapest University of Technology and Economics, Budafoki út 8. — [2]MTA-BME Lendület Magneto-optical Spectroscopy Research Group — [3]Wigner Research Centre for Physics, Budapest, Hungary — [4]Chemical and Engineering Materials Division, Oak Ridge National Laboratory, Oak Ridge, TN, 37831, USA — [5]Experimental Physics V, Center for Electronic Correlations and Magnetism, University of Augsburg, 86135 Augsburg, Germany

$GaMo_4S_8$ is a member of the lacunar spinel family and similarly to its sister compounds, GaV_4S_8 [1] and GaV_4Se_8 [2,3], it presumably hosts a Néel-type skyrmion phase. Magnetization measurements suggest the existence of modulated magnetic phases below T_C=19 K extending down to the lowest temperatures and persisting in magnetic fields up to 1.5-2T. Small-angle neutron scattering (SANS) revealed modulations with a wavelength of approx. 10 nm. Preliminary results on the 3D reciprocal-space structure of the modulation vectors will be presented in comparison with the other lacunar spinels.

[1] Kézsmárki, I. et al. Nature Materials 14, (2015)
[2] Bordács, S. et al. Scientific Reports 7, (2017)
[3] Fujima, Y. et al., Physical Review B 95, (2017)
[4] White, J.S. et al., arXiv:1704.03621 (2017)

MA 51.4 Thu 15:45 EB 407

Thermal expansion and Hall effect of Mn_3ZnN-based noncollinear antiferromagnets — •Sihao Deng[1,2], Cong Wang[3], Gerda Fischer[1], Qingzhen Huang[4], Sasmita Srichandan[1], and Christoph Sürgers[1] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, Karlsruhe, Germany — [2]Fundamental Science on Nuclear Wastes and Environmental Safety Laboratory, SWUST, Mianyang, China — [3]Dept. of Physics, Beihang University, Beijing, China — [4]NIST Center for Neutron Research, NIST, Gaithersburg, USA

Antiferromagnetic Mn_3ZnN-based antiperovskites show a number of interesting magnetic properties due to a non-collinear arrangement of magnetic moments. We investigate the thermal expansion and the magneto-electronic behavior of polycrystalline $Mn_3Zn_{0.77}Mn_{0.19}N_{0.94}$, $Mn_3Zn_{0.83}Mn_{0.15}N_{0.99}$, and $Mn_3Zn_{0.5}Ge_{0.5}N$. Neutron diffraction performed between 5 and 300 K reveals the existence of a triangular non-collinear antiferromagnetic phase below the Neel temperature T_N in these compounds [1, 2]. This magnetic phase with strong spin-lattice coupling gives rise to a zero thermal expansion behavior observed for these compounds. Furthermore, we investigate the Hall effect for temperatures down to 2 K. For $Mn_3Zn_{0.5}Ge_{0.5}N$, we observe a change of the Hall effect at low temperatures, presumably caused by a structural distortion and the accompanied modification of the magnetic texture with a non-coplanar component.

[1] S. Deng, et al., Script. Mater. 146, 18 (2018)
[2] S. Deng, et al., J. Phys. Chem. C 119, 24983 (2015)

MA 51.5 Thu 16:00 EB 407

Magnetic fluctuations in $Mn_{1.4}PtSn$ studied by small-angle neutron scattering — •Aleksandr Sukhanov[1], Praveen Vir[1], Alistair Cameron[2], Andre Heinemann[3], Dmytro Inosov[2], and Claudia Felser[1] — [1]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany — [2]Institut fuer Festkoerperphysik, TU Dresden, D-01069 Dresden, Germany — [3]German Engineering Materials Science Centre (GEMS) at Heinz Maier-Leibnitz Zentrum (MLZ), Helmholtz-Zentrum Geesthacht GmbH, 85747 Garching bei Muenchen, Germany

$Mn_{1.4}PtSn$ belongs to the family of tetragonally-distorted Heulser compounds where non-collinear magnetic order is expected to appear as a result of competition between Heisenberg exchange interaction, the Dzyaloshinskii-Moriya interaction and uniaxial magnetocrystalline anisotropy. Recent examples include the canted antiferromagnetic order in the compound Mn_2RhSn and the lattice of antiskyrmions in $Mn_{1.4}Pt_{0.9}Pd_{0.1}Sn$, which is a structural analogue of the discussed compound [1,2]. Small-angle neutron scattering experiments on an oriented single crystal of $Mn_{1.4}PtSn$ revealed highly-anisotropic nature of the spatial spin-spin correlation function in the range of 100 nm. The latter might be associated with a long-range fluctuation of the ferromagnetic order along one of the principal in-plane crystallographic directions. The scattering patterns show clear dependence on the temperature and the applied magnetic field.

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

15 minutes break

MA 51.6 Thu 16:30 EB 407

Multi-axial spin textures in HoCu — Wolfgang Simeth[1], •Marein Rahn[2], Andreas Bauer[1], Robert Georgii[3], Martin Meven[3], Kirill Nemkovski[4], Sebastian Mühlbauer[3], Tobias Schrader[3], Anatoliy Senyshyn[3], Bachir Ouladdiaf[5], and Christian Pfleiderer[1] — [1]Technische Universität München — [2]Los Alamos National Laboratory — [3]Forschungs-Neutronenquelle Heinz Maier-Leibnitz (FRM II) — [4]Forschungszentrum Jülich — [5]Institut Laue-Langevin

The rare-earth intermetallic compound HoCu condenses in the centrosymmetric CsCl-structure (space group Pm$\bar{3}$m). As a consequence of several competing interactions (itinerant, indirect, and quadrupolar exchange interactions as well as crystal electric fields), a rich magnetic phase diagram with a multitude of phase pockets unfolds. In these phases, the localized 4f magnetic moments of the rare earth atoms order in complex arrangements [1]. For a proper magnetic structure determination, several neutron techniques were used. Data for Rietveld refinement (using Jana2006 [2]) were collected at a four-circle diffractometer. Combined with a XYZ polarization analysis the possible solutions were narrowed down. Ambiguities due to multi-domain effects were suppressed by applying symmetry-breaking magnetic fields. We find that the compound orders in multi-axial AFM structures as well as large-unit-cell modulated AFM structures (~ 15 nm) akin to the helifan-texture in elemental Ho. [1] P. Morin and D. Schmitt, J. Magn. Magn. Mater. 21, 243 (1980). [2] V. Petricek, M. Dusek and L. Palatinus, Z. Kristallogr. 229(5), 345 (2014).

MA 51.7 Thu 16:45 EB 407

Lattice relaxation effects of the spin-ice $Dy_2Ti_2O_7$ — •T. Stoeter[1,2], T. Nomura[2], S. Granovsky[1], M. Doerr[1], O. A. Petrenko[3], G. Balakrishnan[3], S. Zherlitsyn[2], and J. Wosnitza[1,2] — [1]Institut für Festkörper- und Materialphysik, TU Dresden — [2]Hochfeld-Magnetlabor Dresden (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf — [3]Department of Physics, University of Warwick

$Dy_2Ti_2O_7$ and $Ho_2Ti_2O_7$ have attracted enormous scientific interest because of the unusual spin-ice ground state and exotic excitations – magnetic monopoles. In this work, we investigated how the lattice reacted to the change of the monopole density from the spin-ice through the Kagome ice to the saturated monopole phase and whether the very slow monopole dynamics predicted in theory were also detectable in lattice effects. We have performed magnetostriction and thermal-expansion measurements with a capacitive dilatometer on $Dy_2Ti_2O_7$ at temperatures down to 0.28 K to explore the lattice effects in the different regimes: Indeed, we have observed a field-dependent lattice anomaly and have found lattice relaxation effects which could be related to previously proposed monopole dynamics. This research has been supported by the DFG within project C01 of SFB 1143.

MA 51.8 Thu 17:00 EB 407

Antiferromagnetic dynamics in time and space — •Nele Thielemann-Kühn[1,2,3], Daniel Schick[1], Niko Pontius[1], Alessandro Romualdi[1,3], Rolf Mitzner[1], Karsten Holldack[1], Alexander Föhlisch[1,2], and Christian Schüssler-Langeheine[1] — [1]Institut für Methoden und Instrumentierung der Forschung mit Synchrotronstrahlung, Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [2]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Straße 24/25, 14476 Potsdam, Germany — [3]Fachbreich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

With combined time [1]- and depth-resolved [2] x-ray magnetic resonant diffraction we studied optically induced antiferromagnetic dynamics in the 4f metal dysprosium. This allows us to draw not only conclusion about the temporal development but also on the spatial evolution of the magnetic order after exposure to a pump-laser pulse. We find a complex depth dependent quenching behavior of the magnetic order indicative for the interplay of different delocalized as well as local excitation channels. Further, on longer time scales, we observe two clearly distinguishable regions with different magnetic properties within the sample hinting to a long-living non-equilibrium state of the 4f magnetic system.

[1] H. Ott et al., Phys. Rev. B 82, 214408 (2010).
[2] N. Thielemann-Kühn et al., Phys. Rev. Lett. 119, 197202 (2017).

MA 51.9 Thu 17:15 EB 407

Electronic and magnetic properties of the 2H-NbS_2 and TaS_2 compounds intercalated by $3d$ transition metals — •Svitlana Polesya[1], Sergiy Mankovsky[1], Sebastian Mangelsen[2], Wolfgang Bensch[2], and Hubert Ebert[1] — [1]Dept. Chemistry, LMU Munich, D-81377 Munich, Germany — [2]Institute of Inorganic Chemistry, 24118 Kiel, Germany

The electronic structure and magnetic properties of the 2H-NbS_2 and 2H-TaS_2 compounds intercalated by 3d-elements for various 3d-concentrations have been investigated by means of the Korringa-Kohn-Rostoker (KKR) method. Investigations have been performed for the systems with and without atomic ordering of the 3d-element on its sublattice. Magnetic torque calculations have been performed to study the magneto-crystalline anisotropy (MCA) of the compounds for the ground state ($T = 0$ K). The calculated isotropic exchange coupling parameters have been used in MC simulations to investigate the magnetic structure and finite temperature magnetic properties of the systems. The calculations give rather strong interatomic Dzyaloshinskii-Moriya interactions (DMI) that can give rise to a helimagnetic structure as it occurs in $Cr_{1/3}NbS_2$ exhibiting FM order if the DMI is neglected. The negative exchange interactions in $Fe_{1/3}NbS_2$ results in a frustrated magnetic structure in line with experiment. The composition and temperature dependent transport properties have been investigated and compared with available experimental results.

MA 52: Poster II

Time: Thursday 15:00–18:00 Location: Poster C

MA 52.1 Thu 15:00 Poster C

Time-resolved Raman scattering in exotic magnetic materials — •Rolf B. Versteeg[1], Anuja Sahasrabudhe[1], Jingyi Zhu[1], Christoph Boguschewski[1], Petra Becker[2], and Paul H.M. van Loosdrecht[1] — [1]II. Physikalisches Institut, Universität zu Köln, Zülpicher Straße 77, D-50937 Köln, Deutschland — [2]Abteilung Kristallographie, Institut für Geologie und Mineralogie, Universität zu Köln, Greinstraße 77, D-50937 Köln, Deutschland

Magnetic materials show fascinating physical phenomena when brought out of their thermal equilibrium state. Many of these phenomena show a large potential towards applications. For strongly perturbed magnetic systems, these phenomena include magnetization reversal, non-thermal ultrafast magnetization recording, and the creation of metastable light-induced states. Closer to equilibrium non-thermal states can provide insight into energy and angular momentum transfer between the lattice, electronic, orbital and magnetic degrees of freedom. A less common technique to study magnetization dynamics is presented: time-resolved spontaneous Raman scattering. This technique allows to simultaneously track transient changes in quasiparticle population, excitation energies, and optical constants related to the lattice and magnetic degrees of freedom. It thereby provides a unique way to study magnetization dynamics in exotic magnetic materials, such as the helimagnet Cu_2OSeO_3, or other net-zero magnetization materials like spin cycloids and antiferromagnets.

MA 52.2 Thu 15:00 Poster C

Layout of a new experiment to measure ultrafast spin dynamics — •Marc Terschanski, Fabian Mertens, Stefano Ponzoni, Davide Bossini, and Mirko Cinchetti — Experimentelle Physik 6, TU Dortmund, Otto-Hahn-Straße 4, 44227 Dortmund

In this contribution, we will present the layout of a newly-established experimental setup for the ultrafast manipulation of the magnetic order in solids. The setup is based on a turn-key amplified laser system with a repetition rate up to 1 MHz. This system has an output of 20 W and pulses with femtosecond duration. Using two optical parametric amplifiers it is possible to tune the photon energy of both the pump and probe beam independently from 0.5 eV to 3.5 eV. The sample is positioned on a cryostat in a superconducting magnet allowing to cool down to 4 K and apply strong DC-magnetic (9 T) and electric fields.

Investigating ultrafast spin dynamics by detecting magneto-optical effects demands to measure rotation or ellipticity of the probe polarization. In this regard designing and building a balanced detection scheme operating up to 1 MHz and able to integrate the signal of single-pulses is one of the major challenges. Therefore we will present the layout of the setup with special attention given to the home build detector.

MA 52.3 Thu 15:00 Poster C

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

The complex phenomenon arising after a magnetic film is excited by a femtosecond laser pulse is studied using a Monte Carlo trajectory simulation. In this stochastic model we will include not only spin-dependent scattering processes and spin-flip probabilities, but also the electron-electron interaction. The magnetization dynamics will be investigated by using a two-bands dynamic model and it will be first applied to the case of Nickel. The results of this simulation contain the time evolution of the electron number, their energy distribution, the energy dissipation and the quenching of the magnetization.

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

MA 52.4 Thu 15:00 Poster C

Ultrafast demagnetization dynamics including spin and charge transport. — •Sanjay Ashok, Sebastian T. Weber, Johan Briones, and Baerbel Rethfeld — Fachbereich Physik and OPTIMAS Research Center, TU Kaiserslautern, Kaiserslautern, Germany.

Subpicosecond Demagnetization of ferromagnetic materials due to excitation with an ultrafast laser pulse was discovered by Beaurepaire et. al. in 1996 [1]. Understanding its mechanism is still an important problem in cutting edge physics due to its applicability in faster spintronic and magnetic data storage devices.

A recently proposed μT-model [2] traces the equilibration of chemical potentials and temperatures of spin-up and spin-down electrons seperately. Their dynamics is modelled using coupled transport equations. So far, ultrafast demagnetization using μT-model has been studied only in cases where the thickness of the sample is of the order of penetration depth (where transport can be neglected). Here, we study the space and time resolved dynamics in case of thicker samples including the transport and present preliminary results.

References:

[1] E. Beaurepaire, J.-C. Merle, A. Daunois and J.-Y. Bigot, Phys. Lett. 76, 4250 (1996).

[2] B. Y. Mueller and B. Rethfeld, Phys. Rev. B 90, 144420 (2014).

MA 52.5 Thu 15:00 Poster C

Element-selective investigation of femtosecond spin dynamics in NiPd magnetic alloys using extreme ultraviolet radiation — •Seung-gi Gang[1], Roman Adam[1], Moritz Plötzing[1], Moritz von Witzleben[1], Christian Weier[1], Umut Parlak[1], Daniel E. Bürgler[1], Jan Rusz[2], Pablo Maldonado[2], Peter M. Oppeneer[2], and Claus M. Schneider[1] — [1]Peter Grünberg Institut PGI-6, Research Centre Jülich, 52425, Jülich, Germany — [2]Department of Physics and Astronomy, Uppsala University, P.O. Box 516, SE-75120 Uppsala, Sweden

We studied the influence of spin-orbit coupling on femtosecond spin dynamics in NiPd alloys by optically pumping the system with infrared (1.55eV) laser pulses and subsequent recording of the transient resonant reflectivity using synchronized extreme ultraviolet light. The measurements were performed in the transversal magneto-optical Kerr effect geometry. The measurements with XUV light enables separate, but simultaneous detection of spin dynamics in the elemental subsystems with femtosecond time resolution. In static measurements, we measured an induced bipolar magnetic asymmetry of the Pd subsystem due to exchange coupling of the Pd subsystem to the ferromagnetic Ni subsystem. In dynamic measurements, we observed spin dynamics in $Ni_{0.5}Pd_{0.5}$ at both the Ni- and Pd-edges with element selectivity. Increasing the Pd concentration results in a shorter demagnetization time. Here, spin-flip scattering probability plays a critical role in the control of the demagnetization time. The observed behavior is ascribed to an increase of the Pd-mediated SOC in the system.

MA 52.6 Thu 15:00 Poster C

Electron-phonon scattering in Ni studied by temperature dependent RIXS. — •Artur Born, Régis Decker, Robby Büchner, Anette Pietzsch, and Alexander Föhlisch — Helmholtz Zentrum Berlin

In order to study electron-phonon interaction, we measured electron-phonon scattering rates in nickel, using temperature dependent Resonant Inelastic X-ray Scattering (RIXS). By exciting the electrons into the continuum, we created 2p core holes and observed the radiative decay from s and/or d orbitals. By changing the temperature, we created a controlled amount of phonons and got a direct access to the electron-phonon scattering rate in the valence band. We could observe a temperature dependent loss of intensity in the valence to p1/2 decay, which indicates an angular momentum transfer between the valence electrons and the lattice. The angular momentum transfer by electron-phonon scattering was proposed as a main channel for ultrafast spin dissipation, the so-called Elliott-Yafet (EY) scattering in order to explain ultrafast demagnetization processes [1]. In this study, we present a new approach to get access to the EY scattering only, and eliminate laser-induced components of the demagnetization process like super-diffusive spin transport or optical spin manipulations.

[1] B. Koopmans et.al. Explaining the paradoxical diversity of ultrafast laser-induced demagnetization. Nature Mat. 9, 259-265, (2009).

MA 52.7 Thu 15:00 Poster C

Resonant interaction of coherent magnons and phonons in a ferromagnetic nanograting — •Felix Godejohann[1], Alexey Scherbakov[1,2], Boris Glavin[3], Serhii Kukhtaruk[1,3], Mu Wang[4], Alexey Salasyuk[2], Alexey Danilov[1], Andrew

Rushforth[4], Polina Nekludova[5], Sergei Sokolov[5], Andrey Elistratov[6], Dimitri Yakovlev[1,2], Andrey Akimov[4], and Manfred Bayer[1,2] — [1]Exp. Phys. 2, TU Dortmund, Germany — [2]Ioffe Inst., RAS, St. Petersburg, Russia — [3]Dept. of Theo. Phys., V.E. Lashkaryov Inst. of Semiconductor Phys., Kyiv, Ukraine — [4]School of Phys. and Astronomy, Univ. of Nottingham, UK — [5]Inst. of Nanotech. of Microelectronics, RAS, Moscow, Russia — [6]All-Russia Research Inst. of Automatics, Moscow, Russia

We investigate the magneto-phonon interaction in a ferromagnetic nanograting produced by focused ion beam in a 100 nm $Fe_{0.81}Ga_{0.19}$ film. The nanograting with lateral period of 150 nm consists of parallel grooves of 40 nm depth and width milled along [110]-crystallographic direction. We perform magneto-optical time-resolved measurements in a conventional pump-probe scheme with micron spatial resolution: the femtosecond pump pulse excites the nanograting, while the probe pulse serves to detect coherent lattice and magnetic response in time domain. We observe interaction of the localized surface phonon mode at the frequency of 20 GHz and quantized magnon spectrum. By external magnetic field we tune a certain magnon mode to the resonance with coherent phonons to control its spectral amplitude and lifetime.

MA 52.8 Thu 15:00 Poster C

Magnetization dynamics in laser-excited alloys
— •Sebastian T. Weber, Sanjay Ashok, Johan Briones, and Baerbel Rethfeld — Department of Physics and Research Center Optimas, University of Kaiserslautern, Erwin Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany

Irradiating ferromagnetic films with an ultrashort laser pulse leads to a quenching of the magnetization on a subpicosecond timescale [1]. With the help of a spin-resolved Boltzmann description, which allows to describe microscopic collision processes including spin-flips, we have identified the equilibration of chemical potentials of majority and minority electrons as a driving force for ultrafast magnetization dynamics [2].

Since the discovery of ultrafast demagnetization, a multitude of questions and challenges arised. One of the heavily discussed topics is the element-specific dynamics in exchange coupled ferromagnetic alloys [3]. We calculate the joint and partial density of states using DFT methods. The results are put into kinetic simulations [2] and temperature-based descriptions [4]. Here, we want to extend existing models, to trace the electron dynamics with spin-resolution and in dependence on the material in the alloy.

[1] E. Beaurepaire et al., PRL 76, 4250 (1996)
[2] B. Y. Mueller et al., PRL 111, 167204 (2013)
[3] S. Mathias et al., PNAS 109, 4792 (2012)
[4] B. Y. Mueller et al., PRB 90, 14420 (2014)

MA 52.9 Thu 15:00 Poster C

Development of an experimental setup for ultrafast imaging with high harmonics — •Michael Lohmann, Sergey Zayko, Ofer Kfir, and Claus Ropers — 4th Physical Institute - Solids and Nanostructures, University of Göttingen, 37077 Göttingen, Germany

High-harmonic generation (HHG) is a unique source for spatially resolved quantitative studies of nanoscale polarisation anisotropies [1] leading to high-resolution magneto-optical imaging using lensless techniques [2]. However ultrafast HHG imaging remains challenging.

Here, we present the development of a pump-probe setup to extend the capabilities of our HHG-microscope for comprehensive studies of ultrafast dynamics in nanostructured solids. Combining nanometer spatial with femtosecond temporal resolution, this instrument will provide for further insights into ultrafast processes in materials science, including ultrafast magnetism.

[1] Zayko *et al.*, Optica, **3**(3) (2016)
[2] Kfir and Zayko *et al.*, in press

MA 52.10 Thu 15:00 Poster C

No significant effect of spin-pumping in Fe/Ag/Pt heterostructures — •Paul Wendtland, Babli Bhagat, Michael Farle, and Florian M. Römer — Fakultät für Physik und Center for Nanointegration (CENIDE) Universität Duisburg-Essen

Goal of this experiment was to determine the influence of conductive capping layers on the magnetic damping in an Fe thin film.

We created an epitaxial 5 nm Fe film on GaAs(100) and performed in-situ multifrequency Ferromagnetic Resonance (FMR) measurements from 9-15 GHz in [110]-direction. The static properties were determined as well. The *same* film was then capped with increasing amounts of Ag (up to 25 nm) and finally Pt (4 nm), with FMR measurements conducted in between.

By fitting the FMR lines with a dyson-shape model, we determined the FMR linewidth with an accuracy of about 5 %. The resulting Gilbert damping factors are in the range of $((3.8 \ldots 4.1) \pm 0.3) \cdot 10^{-3}$ without a systematic capping dependence. Thus, contrary to theoretical predictions, no effect of spin-pumping was observed as the Gilbert damping factor did not change within the error bars. However, a frequency-independent linewidth increase of up to 80 % was observed.

MA 52.11 Thu 15:00 Poster C

Ferromagnetic Resonance measurements on ultrathin Yttrium-Iron-Garnet grown by LPE — •Ronny Thomas[1,2], Julia Osten[1], Tobias Schneider[1,2], Oleksii Surzhenko[3], Olav Hellwig[1,2], Jürgen Lindner[1], Kilian Lenz[1], and Carsten Dubs[3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physic and Materials Research, Bautzner Landstraße 400, 01328 Dresden — [2]Technische Universität Chemnitz, Straße der Nationen 62, 09111 Chemnitz — [3]INNOVENT e.V. Technologieentwicklung, Prüssingstraße 27B, 07745 Jena

Yttrium-Iron-Garnet (YIG) is known to have one of the lowest Gilbert-damping parameter ($\alpha \sim 10^{-5}$) of all magnetic materials, making it interesting for spintronics and magnonics. One of the most promising application is to use spin-waves for data processing, faced with the problem of fabricating ultrathin YIG-films with the same magnetic properties as their bulk analogue.

Two different YIG-series, each with different thicknesses in the range of 10-80 nm were grown on (111) oriented GGG substrates by liquid phase epitaxy in lead oxide-boron oxide based high-temperature solutions. Using VNA-FMR we determine the anisotropy and damping parameters performing frequency-dependent measurements over a range of 1-40 GHz as well as angle-dependent measurements.

MA 52.12 Thu 15:00 Poster C

Magnetic Damping of normal metal/CoFe heterostructures — •Luis Flacke, Mathias Weiler, Matthias Althammer, Stephan Geprägs, and Rudolf Gross — Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany

The generation of high frequency from a dc-current is an important aspect in microwave technology. Such a generation can be achieved by driving auto-oscillations in a ferromagnet (FM) using a pure spin current generated by the spin Hall effect in an adjacent normal metal (NM) by a dc charge current drive. The required electrical current densities J to achieve auto-oscillations are still of the order of $10^7\,\mathrm{A\,cm^{-2}}$ [1]. A possible pathway to reduce J is to use materials with low intrinsic magnetic damping. To this end, we fabricated NM/FM/NM heterostructures by DC-sputtering using $Co_{25}Fe_{75}$ as the FM and Ta, Pt, Al as the NM and varying their respective deposition parameters and thicknesses. The magnetic properties of these multilayers were then investigated by broadband ferromagnetic resonance spectroscopy at room temperature. From these measurements we extracted the Gilbert damping parameter for all investigated multilayers. We discuss the obtained damping parameters with respect to contributions originating from spin pumping and intrinsic effects. Moreover, we show how our results can be employed to optimize auto-oscillations in such multilayerstructures based on the $Co_{25}Fe_{75}$ alloys.
[1] C. Stamm et al., Phys. Rev. Lett. **119**, 087203 (2017)

*Financial support via the Nanosystems Initiative Munich is gratefully acknowledged.

MA 52.13 Thu 15:00 Poster C

Optically Modified Spin Pumping — •Tanja Strusch, Babli Bhagat, Michael Farle, and Florian M. Römer — Fakultät für Physik und Center for Nanointegration (CENIDE) Universität Duisburg-Essen

We will present a setup in which we can determine the influence of non polarized and circular polarized light on the different damping mechanisms as a function of wavelength, polarization, helicity, intensity and angle between magnetization (M) and input direction of the polarized light.

Therefore we have a new setup in which it is possible to do multifrequency Ferromagnetic Resonance (FMR) and Magneto-Optical Kerr Effect (MOKE) measurements simultaneously. The FMR setup is used with a microwave short-circuit and has a frequency range of 1 up to 40 GHz. In addition the setup enables us to do measurements with and without field modulation. The MOKE setup can be used at longitudinal and transversal geometry and one can measure from infrared to visible light by using different types of lasers.

By combining this two setups we will determine the interaction of Ferromagnetic Resonance with light of different polarization, helicity and wavelength.

MA 52.14 Thu 15:00 Poster C

Relaxation of a classical spin coupled to a conventional superconductor — •Cassian Plorin and Michael Potthoff — I. Institut für Theoretische Physik, Universität Hamburg

The effect of a superconducting substrate on the real-time dynamics of the local magnetic moment of an adatom is investigated numerically within a variant of the s-d exchange model. To this end, we solve the equations of motion for a classical spin, which is exchange-coupled to the local magnetic moment of a conduction-electron system. The electron system is given as a negative-U Hubbard model and treated by a mean-field decoupling. Its real-time dynamics is governed by a von-Neumann-type equation for the normal and for the anomalous blocks of the one-particle reduced density matrix.

We study the time dependence of the classical spin, of the electron spin density and of the local s-wave order parameter after a sudden flip of the direction of a magnetic field coupling to the spin. The spin relaxation and the alignment to the new field direction is found to be strongly U-dependent. Incomplete relaxation is observed when the superconducting gap exceeds a certain value. This effect is beyond a Landau-Lifschitz-Gilbert-type approach but can be understood on the level of linear-response theory in the exchange coupling. The feedback of the spin dynamics on the superconducting order parameter, however, is beyond linear-response theory.

MA 52.15 Thu 15:00 Poster C

Ab-initio analysis of longitudinal and transverse spin relaxation times of magnetic single adatoms: — •Julen Ibanez-Azpiroz[1], Manuel dos Santos Dias[2], Stefan Blugel[2], and Samir Lounis[2] — [1]Centro de Fisica de Materiales — [2]Forschungszentrum Jülich

We present a systematic *ab initio* investigation of the longitudinal and transverse spin relaxation times of magnetic single adatoms deposited on metallic substrates. Our analysis based on time-dependent density functional theory shows that the longitudinal time, $T_\parallel$, is of order femtosecond while the transverse time, $T_\perp$, is of order picosecond, i.e. $T_\perp \gg T_\parallel$. This comes as a consequence of the different energy scales of the corresponding processes: $T_\parallel$ involves spin-density excitations of order eV, while $T_\perp$ is governed by atomic spin-excitations of order meV. Comparison to available inelastic scanning tunneling spectroscopy $\mathrm{d}I/\mathrm{d}V$ experimental curves shows that the order of magnitude of $T_\perp$ agrees well with our results. Regarding $T_\parallel$, the time scale calculated here is several orders of magnitude faster than what has been measured up to now; we therefore propose that an ultrafast laser pulse measuring technique is required in order to access the ultrafast spin-dynamics described in this work.

MA 52.16 Thu 15:00 Poster C

Towards a complete first principles parameterisation of magnetic materials as input for atomistic spin dynamics simulations — •Mario Galante, Matthew O. A. Ellis, Alessandro Lunghi, and Stefano Sanvito — School of Physics, Trinity College Dublin, Ireland

Atomistic spin dynamics has proven to be an invaluable tool to investigate the behaviour of magnetic nanomaterials. It is based on a Heisenberg spin model, where the spin magnetic moment is localised to each atomic site and obeys the Landau-Lishfitz-Gilbert-like (LLG) equations of motion. The solution of such equations requires the knowledge of some material-dependent microscopic properties such as the interatomic exchange, the magnetic anisotropy and the Gilbert damping. In nanoscale systems strain and interfaces can greatly alter the electronic structure, hence input parameters from *ab-initio* are desirable since they can provide system-tailored and atom resolved information. Furthermore, methods based on density functional theory including spin orbit interactions are suitable to perform high-throughput calculations of such quantities. In this work we analyse the suitability of the recipes provided in Refs. [1,2] to calculate the magnetic anisotropy and the inter-atomic exchange parameters respectively, using our own implementation based on the SIESTA code [3]. We then discuss a new parameter-free method to estimate the Gilbert damping based on a finite difference solution of the Liouville equation. [1] Schmitt *et al*, J. Chem. Phys. 134, 194113 (2011) [2] Korotin *et al*, PRB 91, 224405 (2014) [3] Soler *et al*, J. Phys.: Cond. Mat. 14, 2745 (2002)

MA 52.17 Thu 15:00 Poster C

Electrical detection of internally pumped magnons — •Timo Noack, Vitaliy Vasyuchka, Dymitro Bozhko, Burkard Hillebrands, and Alexander Serga — TU Kaiserslautern, Fachbereich Physik and Landesforschungszentrum OPTIMAS, Germany

The method of parallel parametric pumping is a widely used method for the generation of dence groups of magnons with well defined wavevectors and frequencies. In the process of four-magnon scattering these magnons thermalize in a wide range of energy-momentum spin-wave spectrum. As well, Bose-Einstein condensation of the thermalized magnons is possible at the lowest energy state. In this contribution we show an impact of parametrically pumped, thermalized, and condensed magnons on the electrical detection of spin currents in yttrium iron garnet/platinum bilayers. Therefore, spin pumping magnitude was time dependent measured using the inverse Spin Hall effect (ISHE). In ISHE waveforms an enhancement in the voltage amplitude is observed after the external pumping pulse is switched off. This enhancement is understood as a result of the excitation of secondary magnons at the YIG/Pt interface in the process of nonlinear thermalization of freely evolving parametric magnons. Financial support from the Deutsche Forschungsgemeinschaft in the frame of SFB/TR 49 is acknowledged.

MA 52.18 Thu 15:00 Poster C

Material selection for spin-transfer-torque magnetic random access memories — •Emanuele Bosoni and Stefano Sanvito — School of Physics and CRANN, Trinity College Dublin, College Green, Dublin 2, Ireland

The sensitive element in a Spin-Transfer-Torque Magnetic Random Access Memory (STT-MRAM) is formed by two ferromagnetic layers sandwiching an insulator acting as a tunnel barrier. At present the state-of-the-art materials set for the STT-MRAM technology is CoFeB/MgO, but it is not clear whether further improvement over this will be possible. Fundamental research is then needed to design new efficient junctions and, in this respect, *ab-initio* simulations offer a powerful tool to carry out a systematic study.

In this contribution we describe a computational strategy for the selection of promising materials for STT-MRAMs. Some peculiar material-related features are essential for the device operation and looking for these properties will lead to a pre-selection of suitable ferromagnets and insulators to be combined into efficient STT-MRAM structures. In order to accomplish this goal, we have adopted an approach based on high-throughput Density Functional Theory (DFT) calculations. Our guiding criterion is to appropriately match the complex band-structure of the insulator with the real one of the magnetic electrodes along directions where the growth of heterojunctions is possible. The result of such screening offers a preliminary step before carrying out more computational demanding simulations on the transport and STT properties of the junction itself.

MA 52.19 Thu 15:00 Poster C

Ultrafast demagnetization dynamics in an FePtMn alloy — •Cinja Seick[1], Ute Bierbrauer[2], Moritz Hofherr[2], Nataliia Safonova[3], Manfred Albrecht[3], Benjamin Stadtmüller[2], Martin Aeschlimann[2], Daniel Steil[1], and Stefan Mathias[1] — [1]I. Physikalisches Institut, Universität Göttingen, Germany — [2]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [3]Institute of Physics, University of Augsburg, Germany

The speed and efficiency of ultrafast magnetization dynamics is known to depend on the interplay of the electron, spin, and lattice system in combination with the magnetic moments and the exchange interaction. In order to study the influence of the exchange interaction, one approach is to study alloys with varying with varying stoichiometry and hence exchange coupling between different magnetic constituents. In our work, we chose a sample system with two magnetic sub-lattices with varying contributions, namely the alloy $[\mathrm{FePt}]_{1-\chi}\,\mathrm{Mn}_\chi$, which we study with the time-resolved magneto-optical Kerr effect. In this material system, we consistently find a peculiar speed-up of the average demagnetization time at intermediate pump fluencies. In order to understand this process, we use a modified microscopic three temperature model with two interacting spin systems.
We will present experimental results and first simulations.

MA 52.20 Thu 15:00 Poster C

Nonlinear response of thin magnetic films to short electromagnetic pulses — •Alexander F. Schäffer and Jamal Berakdar — Institute of Physics, Martin-Luther-Universität Halle-Wittenberg, 06099 Halle (Saale), Germany

We study the response of thin magnetic layers affected by electromagnetic fields induced by short optical or electron pulses, beyond the linear response regime. As multiple excitations exist in such systems, a cornucopia of possible interaction mechanisms has to be investigated. In this work, we will present consequences of the excited thermal, electric and magnetic components on the subsequent magnetization dynamics.

MA 52.21 Thu 15:00 Poster C

Phase-sensitive Detection of Inverse Spin-Orbit Torques in Normal Metal/Ferromagnet Bilayers at GHz-Frequencies — •Lukas Liensberger[1,2], Satya Prakash Bommanaboyena[3], Björn Gliniors[3], Oliver Gückstock[4], Tom Seifert[4], Tobias Kampfrath[4], Rudolf Gross[1,2,5], Markus Meinert[3], and Mathias Weiler[1,2] — [1]Walther-Meißner-Institut, Garching — [2]Physik-Department, Technische Universität München, Garching — [3]Center for Spinelectronic Materials and Devices, Department of Physics, Bielefeld University, Bielefeld — [4]Department of Physical Chemistry, Fritz Haber Institut of the Max Planck Society, Berlin — [5]Nanosystems Initiative Munich, Munich

Quantitative understanding of direct and inverse spin-orbit torques (SOT) in ferromagnet/normal metal bilayers is required to develop novel and efficient spintronic devices. Established methods to quantify SOTs require patterning and/or impedance matching. Here, we use a novel, contactless inductive measurement technique to quantify the SOTs in different normal metal/ferromagnet bilayer systems at room temperature and microwave frequencies using a coplanar waveguide (CPW) and a vector network analyzer [1]. This method is based on the broadband ferromagnetic resonance technique and utilizes that the CPW detects any source of AC magnetic flux. The phase-sensitive method can distinguish between field- and damping-like SOTs. We study SOTs in thin film bilayers consisting of the ferromagnet CoFeB and varying binary alloys of TaAu and AuPt as well as W with varied degree of oxidation. [1] A. Berger *et al.*, arXiv: 1611.05798 (2016)

MA 52.22 Thu 15:00 Poster C

Time resolved MOKE measurements with calibrated lattice temperatures — •Lisa Willig[1,3], Jan-Etienne Pudell[1], Marc Herzog[1], Matthias Kronseder[2], Christian Back[2], Alexander von Reppert[1], and Matias Bargheer[1,3] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany — [3]Helmholtz-Zentrum Berlin, Berlin, Germany

We measure the response of the spin system in thin Ni films after excitation with a 800nm pump pulse via the time-resolved magneto-optical Kerr effect (MOKE) for various pump fluences. We calibrate the absorbed energy by ultrafast x-ray diffraction (UXRD), which is sensitive to the transient temperature of the Nickel lattice. We are particularly interested in high fluence measurements, where the lattice temperature rises above the Curie temperature. The tr-MOKE signal confirms that the spin system is fully disordered for long times up to 100 ps. We analyze the recovery of the magnetization.

MA 52.23 Thu 15:00 Poster C

Spin waves in CoFeB thin films dominated by Dzyaloshinskii-Moriya interaction — •Tobias Fischer[1,2], Frank Heussner[1], Samridh Jaiswal[3,4], Gerhard Jakob[3], Mathias Kläui[2,3], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Erwin-Schrödinger-Straße 56, 67663 Kaiserslautern — [2]MAINZ Graduate School of Excellence, Staudingerweg 9, 55128 Mainz — [3]JGU, Institut für Physik, Staudingerweg 7, 55128 Mainz — [4]Singulus Technologies AG, Hanauer Landstraße 103, 63796 Kahl am Main

The asymmetric exchange contribution in ultra-thin magnetic films with both broken inversion symmetry and an adjacent capping material with a large spin-orbit interaction can lead to a strong interfacial Dzyaloshinskii-Moriya interaction (DMI) [1]. As a result, an additional term linear in the spin-wave wave vector appears in the dispersion relation of spin waves. Brillouin light scattering (BLS) spectroscopy is employed to probe the spin-wave spectrum and to determine the DMI constant. We present results of the investigation of the spin-wave spectrum in ultra-thin CoFeB (0.6 nm) films deposited on Pt and W, respectively. For both single and multilayers these findings are compared with results obtained earlier using methods other than BLS. Furthermore, a detailed analysis of the signal peak behavior is provided.

Financial support within the SFB/TRR 173 *Spin+X* is gratefully acknowledged.

[1] A. A. Stashkevich *et al.*, Phys. Rev. B **91**, 214409 (2015).

MA 52.24 Thu 15:00 Poster C

Photon energy dependent fs-demagnetization dynamics of thin Ni films — •Jonas Hoefer, Sebastian Weber, Ute Bierbrauer, David Schummer, Sanjay Ashok, Moritz Barkowski, Benjamin Stadtmüller, Bärbel Rethfeld, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany

After the first observation of the ultrafast demagnetization process of ferromagnetic thin films on the femtosecond timescale, a huge experimental and theoretical effort was devoted to reveal the microscopic mechanism governing the ultrafast optically induced loss of magnetic order in ferromagnetic materials.

In this context, almost all experimental studies so far employed fs light pulses of 1.55eV to trigger the fs-demagnetization dynamics. Hence, the role of the photon energy of the exciting light pulse has not been investigates so far. Therefore, we have implemented an all optical time resolved MOKE setup with variable pump photon energy in the range of 1.55 to 3.10eV. As prototypical system, we first investigated the ultrafast demagnetization dynamics of thin Ni films on insulating and conducting substrates for various excitation photon energies. The characteristic parameters of the demagnetization process, i.e., the demagnetization time and the quenching of magnetization, will be compared to simulations describing the non-equilibrium dynamics of the spin-carrying excited electrons.

MA 52.25 Thu 15:00 Poster C

Towards ultrafast transmission electron microscopy at high repetition rates — •John H. Gaida, Marcel Möller, and Claus Ropers — 4th Physical Institute, Georg-August-University, Göttingen, Germany

Lorentz microscopy is a widely applied technique for the nanoscale mapping of magnetization structures. Its adaptation to time-resolved imaging offers fascinating prospects for studying ultrafast magnetization dynamics.

The Göttingen Ultrafast Transmission Electron Microscope (UTEM) is a newly developed instrument, which allows to study ultrafast magnetization and demagnetization dynamics, which are either optically induced or driven by radiofrequency excitation [1].

In this contribution, we investigate the generation of photoelectron pulses and the possibility to carry out ultrafast Lorentz microscopy at high MHz repetition rates.

[1] A. Feist et al., Ultramicroscopy 176 (2016)

MA 52.26 Thu 15:00 Poster C

Fluence-dependent ultrafast magnetization dynamics in Gd and Tb thin films and TbGd bilayers studied by XMCD in reflection — •Markus Gleich[1], Kamil Bobowski[1], Dominic Lawrenz[1], Can Çağıncan[1], Niko Pontius[2], Daniel Schick[2], Christoph Trabant[1], Marko Wietstruk[1], Björn Frietsch[1], Christian Schüssler-Langeheine[2], and Martin Weinelt[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin

We have investigated the fluence-dependent ultrafast magnetization dynamics of lanthanide thin films. Single-crystalline films were grown on a W(110) substrate providing sufficient cooling to observe de- and remagnetization in pump-probe spectroscopy. The transient magnetization was probed element-specifically by X-ray magnetic circular dichroism in reflection at the FEMTOSPEX facility of BESSY II. All samples show a two-step demagnetization as observed in previous experiments on Gd and Tb [1-4]. On the ultrafast time scale (< 2 ps) Tb is demagnetized most effectively followed by Gd and, surprisingly, Gd in a 3 ML Tb on Gd bilayer. On the long time scale Tb shows a much faster magnetization recovery than Gd. We attribute the difference in dynamics to the stronger spin-lattice coupling in Tb.

[1] M. Wietstruk *et al.*, Phys. Rev. Lett. **106**, 127401 (2011).

[2] M. Sultan *et al.*, Phys. Rev. B **85**, 184407 (2012).
[3] A. Eschenlohr *et al.*, Phys. Rev. B **89**, 214423 (2014).
[4] K. Bobowski *et al.*, J. Phys.: Condens. Matter **29**, 234003 (2017).

MA 52.27 Thu 15:00 Poster C

Critical exponents of magnon transport coefficients — Alexander Mook[1], •Till Hanke[1], Jürgen Henk[1], and Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität, D-06120 Halle — [2]Max-Planck-Institut für Mikrostrukturphysik, D-06120 Halle

The spin and heat transport through magnetic insulators is a centerpiece in the fields of spintronics, spin caloritronics, and magnonics. We report on the development of a method that simulates magnon transport over the entire temperature range, from zero Kelvin up to and beyond the critical temperature. It is based on equilibrium atomistic spin dynamics simulations and the Green-Kubo relations [1], relating the equilibrium fluctuations of currents to the magnon transport coefficients, such as the spin conductivitiy σ, the spin Seebeck coefficient S, and the thermal conductivity κ. We study the dependence of these conductivities on temperature in generic three-dimensional magnets. Focussing on the thermal second-order phase transition from the ordered to the paramagnetic phase, we extract the critical exponents of σ, S, and κ. The connection to recent experimental results on the spin Seebeck effect in yttrium iron garnet [2] is discussed.

[1] A. Mook *et al.*, Phys. Rev. B **94**, 174444 (2016)
[2] K. Uchida *et al.*, Phys. Rev. X **4**, 041023 (2014)

MA 52.28 Thu 15:00 Poster C

Extrinsic Spin Nernst effect and thermoelectric transport coefficients — •Franziska Töpler[1], Christian Herschbach[1], Dmitry Fedorov[2], Martin Gradhand[3], and Ingrid Mertig[1,4] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]University of Luxembourg, L-1511 Luxembourg, Luxembourg — [3]University of Bristol, Bristol, United Kingdom — [4]Max Planck Institute of Microstructure Physics, Halle, Germany

The field of spin caloritronics investigates the combined transport of spin, charge and heat. The corresponding currents are coupled to thermal and electric gradients via linear transport coefficients [1,2]. We calculate the extrinsic contribution to these coefficients caused by skew-scattering. For this purpose we use a fully relativistic KKR-Green's function method and solve the semiclassical Boltzmann equation [3,4]. We present temperature-dependent results for thermopower, spin Nernst angle and efficiency for Cu-based dilute alloys [5]. In case of Au defects we introduce an improved integration method to reduce computational effort and enhance accuracy. We compare results of both procedures for various thermoelectric quantities.

[1] Boona *et al.*, Energy Environ. Sci. **7**, 885 (2014); [2] Bauer *et al.*, Nat. Mater. **11**, 391 (2012); [3] Gradhand *et al.*, PRB **80**, 224413 (2009); [4] Gradhand *et al.*, Phys. Rev. Lett. **104**, 186403 (2010); [5] Tauber *et al.*, Phys. Rev. Lett. **109**, 026601 (2012).

MA 52.29 Thu 15:00 Poster C

Direct Measurements of the Magneto-Caloric Effect of MnFe4Si3 in Pulsed Magnetic Fields — •Nour Maraytta[1], Yurii Skourski[2], Jörg Voigt[1], Karen Friese[1], Jörg Persson[1], Salman Salman[3], and Thomas Brückel[1] — [1]Jülich Centre for Neutron Science JCNS-2 and Peter Grünberg Institute PGI-4, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Dresden High Magnetic Field Laboratory HLD, Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstraße 400, 01328 Dresden. — [3]Physics Department, Al-Quds University, Abu Dis, Palestine

Magnetocaloric Effect forms the basis of magnetocaloric refrigeration technology which is an energy-efficient and environmentally friendly method for cooling [1]. A large single crystal of MnFe4Si3 was grown; this allows one to determine the crystal and magnetic structure of the compound reliably [2].

In this contribution, we will present the direct measurements of ΔTad in pulsed magnetic fields up to 50T using a home-built experimental set-up from HLD [3]. This technique provides nearly adiabatic conditions during the measurements. The results show that the material can by reversibly cycled which is an important requirement for the applications. We will also compare the results to the ones obtained from magnetization measurements in static magnetic fields using PPMS.

[1] K.A. Gschneidner Jr. and V.K. Pecharsky, Int. J. Refrig. 2008, 31, 945 * 961. [2] P. Hering, K. Friese, J. Voigt et.al., Chem. Mat. 2015, 27, 7128-7136. [3] M. G. Zavareh, C. S. Mejía, A. K. Nayak, et.al., Appl. Phys. Lett. 2015, 106.

MA 52.30 Thu 15:00 Poster C

Influence of martensite intercalations on the thermal hysteresis in NiMn-based magnetic shape memory alloys — •Andreas Becker, Jan Peterhanwahr, Joris Swager, and Andreas Hütten — Bielefeld University, 33615 Bielefeld, Center for Spinelectronic and Materials

NiMnX (X=Al,Ga,Sn,In) magnetic shape memory Heusler alloys are considered as promising materials for magnetocaloric cooling applications due to their magnetoelastic coupling near room temperature[1]. However most of them show a very large thermal hysteresis, which can span over several hundreds of Kelvin, limiting their potential in future applications. Therefore efficient mechanisms to change the martensitic transformation behavior have to be found.

Our research showed that rigid substrates increase hysteresis width and residual austenite in NiCoMnAl thin films[2]. We concluded that thin martensite intercalations in those films should be the best available substrate for transforming films. Our aim is to reduce the thermal hysteresis in off-stoichiometric NiCoMnAl thin films, grown by sputter deposition, by preparing multilayer systems, which consist of alternatively grown martensite intercalations and active transforming layers. Stoichiometry of the layers is chosen in such a way that the martensite transformations do not overlap. The phase transition of the active layer is investigated by temperature dependent magnetic, electrical transport and x-ray diffraction measurements.

[1] Liu et al., Nature Materials 11, 7 (2012)
[2] M. Wodniok et al., AIP Advances 7, 056428 (2017)

MA 52.31 Thu 15:00 Poster C

Reversibility of minor hysteresis loops in magnetocaloric Heusler alloys — •T. Gottschall[1,2], E. Stern-Taulats[3], Ll. Mañosa[3], A. Planes[3], K. P. Skokov[1], O. Gutfleisch[1], Y. Skourski[2], and J. Wosnitza[2] — [1]TU Darmstadt, Institute of Material Science, Germany — [2]High Magnetic Field Laboratory (HLD-EMFL), Helmholtz-Zentrum Dresden-Rossendorf, Germany — [3]Departament de Fisica de la Materia Condensada, Facultat de Fisica, Universitat de Barcelona, Spain

The unavoidable existence of thermal hysteresis in these magnetocaloric materials is one of the central challenges limiting their implementation in cooling devices. Transforming the material in minor loops of the thermal hysteresis, however, allows achieving significant reversible effects even when the hysteresis is relatively large. In this work, we focus on the magnetocaloric properties of Heusler alloys under cycling. We compare thermometric measurements of the adiabatic temperature change in low magnetic fields and pulsed field experiments with calorimetric measurements of the isothermal entropy change when moving in minor hysteresis loops driven by magnetic fields [1, 2].

Support of DFG (SPP1599) is gratefully acknowledged.

[1] T. Gottschall et al., Phys. Rev. Applied 5 (2016) 024013.
[2] T. Gottschall et al., Appl. Phys. Lett. 110 (2017) 223904.

MA 52.32 Thu 15:00 Poster C

Magnetic properties of the $Fe_xNi_{8-x}Si_3$ materials, $0\leq x\leq 8$ — •Mohammed Ait Haddouch[1], Simone Gallus[2], Jörg Persson[1], Jörg Voigt[1], Karen Friese[1], and Andrzej Grzechnik[2] — [1]Jülich Centre for Neutron Science-2/Peter Grünberg Institut-4, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [2]Institute of Crystallography, RWTH Aachen University, Jägerstr. 17-19, 52066 Aachen, Germany

In this work, the magnetic properties of the system $Fe_xNi_{8-x}Si_3$ with $0\leq$ x ≤ 8 were investigated by DC magnetization measurements for $1\leq$ x ≤ 6 in the temperature range from 10 K to 900 K. The system features a large number of different crystallographic sites for the magnetic ions, which is a possible ingredient for good magnetocaloric materials. Within the ternary $Fe_xNi_{8-x}Si_3$ system, two different stability fields have been observed [1]. For the $Ni_{31}Si_{12}$ structure types samples with $0\leq$ x ≤ 4 we find magnetic transitions below 380 K evidenced by sudden changes in the slope of the M(T) curves. Even above these temperatures, the samples do not exhibit Curie-Weiss behavior, indicating the existence of another magnetically ordered phase. For $5\leq$ x ≤ 8 samples with the Fe_3Si structure type with compositions exhibit only one phase transition around 800 K. On the basis of our data, a magnetic phase diagram will be proposed over the full range of $Fe_xNi_{8-x}Si_3$ compositions between 0 K and 900 K. We will also derive the magnetic entropy change for the different magnetic transitions of these compound, to check their magnetocaloric effect efficiency.

[1] Gallus et.al, submitted to Solid State Sciences, (2017)

MA 52.33 Thu 15:00 Poster C

Effect of high Mn-doping on magnetocaloric $La(FeSi)_{13}$-based compounds — •Alexandra Terwey[1], Benedikt Eggert[1], Daniela Trienes[1], Joachim Landers[1], Soma Salamon[1], Werner Keune[1], Katharina Ollefs[1], Iliya Radulov[2], Konstantin Skokov[2], Oliver Gutfleisch[2], and Heiko Wende[1] — [1]Faculty of Physics and Center for Nanointegration (CENIDE), University of Duisburg-Essen, Duisburg, Germany — [2]Functional Materials, TU Darmstadt, Darmstadt, Germany

By combining low temperature Mössbauer studies with and without applied magnetic fields and magnetometry, we investigated the effect of Mn-doping with increasing concentrations on $La(FeSi)_{13}$-based compounds and thereby analyzed the coupling of Mn to the Fe sublattices in the system. $La(FeSi)_{13}$-based materials have the potential use as magnetocaloric refrigerants due to a first-order magneto-structural phase transition near room temperature when additionally doped with hydrogen. Mn doping prevents hydrogen segregation. From our Mössbauer studies at low temperatures in applied external magnetic fields we find a decrease in the hyperfine fields with increasing Mn concentration as well as an increase in the spin frustration. This increase in spin frustration points towards a stronger AFM coupling between Fe and Mn and additionally results in a lowering of the saturation magnetization and of the local Fe moment as validated by magnetometry and extracted hyperfine magnetic fields. Funding by the DFG (SPP1599) is acknowledged.

MA 52.34 Thu 15:00 Poster C

Energy flow in the rare earth Dysprosium revealed by Ultrafast X-Ray diffraction — •Alexander von Reppert[1], Jan-Etienne Pudell[1], Azize Koc[2], Karine Dumesnil[3], Matthias Reinhardt[2], Flavio Zamponi[1], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Berlin, Germany — [3]Institut Jean Lamour (UMR CNRS 7198), Université Lorraine, Nancy, France

We present ultrafast x-ray diffraction (UXRD) measurements on nanolayered Dysprosium systems, that serves as a model for the class of heavy rare earth materials (Ho, Gd, Tb, ..), which exhibit large magnetostriction. We excite the material by femtosecond light pulses, which instantaneously heat up the electron gas. The coupling of the deposited energy to spin degrees of freedom and to phonons yields the lattice strain. The measured strain is a result of two stress components acting on the atoms: The stresses due to phonons and spins are proportional to the energies in the phonon and spin systems via effective Grüneisen constants which have opposite signs in these rare earths. By a careful analytic decomposition of the signals we can monitor the heat flow among spins and phonons and observe a long lasting non-equilibrium between the spin and phonon excitations that persists for many nanoseconds.

MA 52.35 Thu 15:00 Poster C

Studying the effect of anisotropy on lattice and magnetization dynamics in FePt — •Lisa Willig[1,3], Paul Haberjoh[1], Jan-Etienne Pudell[1], Olav Hellwig[2], Alexander von Reppert[1], and Matias Bargheer[1,3] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Institut für Physik, Technische Universität Chemnitz, Chemnitz, Germany — [3]Helmholtz-Zentrum Berlin, Berlin, Germany

Here we compare the response of two nanoscopic FePt specimen: granular and continuous films of comparable size upon fs-laser excitation. The FePt particles of the granular film are embedded in carbon matrix and exhibit a much larger out of plane magnetic anisotropy, which is desirable for heat assisted magnetic recording. Ultrafast X-Ray diffraction with a 200 fs time-resolution is used to monitor the lattice dynamics and energy flow in both films. Marked differences appear in the initial strain buildup: The nanoscopic granular film exhibits a delayed onset and strongly reduced amplitude in the out of plane expansion compared to the immediate expansion of the homogeneously excited continuous film, where all in-plane stresses are intrinsically balanced. We complement our findings of the lattice dynamics with magnetization measurements via time-resolved MOKE to present lattice and magnetization of this technologically relevant material under comparable conditions.

MA 52.36 Thu 15:00 Poster C

Lattice response of $TbFe_2$ thin films to ultrashort laser pulse excitation studied by X-Ray diffraction — •Steffen Zeuschner[1], Azize Koc[2], Jan-Etienne Pudell[1], Karine Dumesnil[3], Matthias Reinhardt[2], Flavio Zamponi[1], Marc Herzog[1], Alexander von Reppert[1], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Berlin, Germany — [3]Institut Jean Lamour (UMR CNRS 7198), Université Lorraine, Nancy, France

We present ultrafast X-ray diffraction experiments that quantify the strain waves launched by femtosecond laser excitation. The spatio-temporal temperature and strain profiles suggest a non-linear fluence dependent non-equilibrium electronic heat transport on a picosecond timescale. $TbFe_2$ is a model system known for its giant magnetostriction. Its two constituents Tb and Fe contribute a high crystalline anisotropy, a large effective magnetic moment and a Curie temperature considerably above room temperature. In line with the concept of heat assisted magnetic recording we observe that switching the magnetization by external magnetic fields is facilitated upon laser heating.

MA 52.37 Thu 15:00 Poster C

Spin excitations in antiferromagnetic rare earths drive ultrafast negative thermal expansion — •Jan-Etienne Pudell[1], Alexander von Reppert[1], Flavio Zamponi[1], Matthias Rössle[1,2], Hartmut Zabel[3], Daniel Schick[2], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Berlin, Germany — [3]Institut für Experimentalphysik , Ruhr Universität Bochum, Bochum, Germany

We present ultrafast x-ray diffraction (UXRD) measurements on a nanolayer system of Holmium (Ho), Yttrium and Niobium layers. We excite the samples by femtosecond light pulses, which instantaneously heat up the electron gas. The coupling of this deposited energy to spin degrees of freedom and to phonons, which simultaneously measured in all constituting layers by x-ray diffraction of 200 femtosecond pulses derived from a laser based plasma source. In the helical antiferromagnetic phase of Ho the energy transferred from the electrons to the spin system leads to a pronounced lattice contraction, whereas heating the phonon system leads to a negative stress component. The sign of the measured ultrafast strain profiles changes upon cooling to the AFM phase, yielding direct evidence of the negative driving stress due to spin excitations. By modeling the generated coherent strain wave in the layers we can derive the spatio-temporal stress profiles generated by the phonon and spin contributions.

MA 52.38 Thu 15:00 Poster C

Magnetic skyrmions in metallic multilayers: investigation of the three dimensional magnetic texture and spin-orbit torque engineering — •Nicolas Reyren[1], William Legrand[1], Davide Maccariello[1], Jean-Yves Chauleau[1,2], Nicolas Jaouen[2], Vincent Cros[1], and Albert Fert[1] — [1]Unité Mixte de Physique CNRS/Thales, Univ. Paris-Sud, Université Paris-Saclay, Palaiseau, France — [2]Sychrotron SOLEIL, Gif-sur-Yvette, France

Magnetic multilayers made of repeated trilayers, *e.g.*,(Pt|Co|Ir) with thicknesses of each layer below about 1 nm, are designed to preserve a large effective Dzyaloshinskii-Moriya interaction (DMI) while increasing the total magnetic volume. In such samples, the volume increase is associated to an improved stability of the magnetic textures and, in particular, we showed that skyrmions could be stabilized at room temperature. However, in the case of numerous repetitions, typically above ten for our samples structure, the stray fields of the skyrmion core and the surrounding uniform magnetization which favour "Néel caps", overcome the DMI and lead to non-uniform magnetization along the thickness of the skyrmion. In each individual magnetic layer, the magnetic texture corresponds to a skyrmion, but the chirality of the top and bottom layers can differ. The chirality playing a crucial role for spin-orbit torque induced motion, the samples should be carefully designed in order to improve the skyrmion velocity by taking into account the specifics of the three-dimensional magnetic texture.

MA 52.39 Thu 15:00 Poster C

Effective Hamiltonian descriptions for skyrmion and antiskyrmion dynamics — •Benjamin F. McKeever[1,2], Davi R. Rodrigues[3,2], Matthias Sitte[1], Jairo Sinova[1,4], Artem Abanov[3], and Karin Everschor-Sitte[1] — [1]Institut für Physik, Johannes Gutenberg-Universität, Mainz 55128, Germany — [2]Graduate School Materials Science in Mainz, Mainz 55128, Germany — [3]Department of Physics & Astronomy, Texas A&M University, College

Station, Texas, USA — [4]Insitute of Physics ASCR, 162 53 Phraha 6, Czech Republic

The dynamics of magnetic textures described by the Landau-Lifshitz-Gilbert equation is complex. However, the description of the low energy physics often requires only a reduced set of effective variables. One route to such a description follows a generalization of the method by Thiele, originally introduced for the steady translational motion of rigid domains, involving direct manipulations of the Landau-Lifshitz-Gilbert equation. Here we exploit an alternative, equivalent method that is independent of microscopic details and derives a general effective Hamiltonian description from an action principle. The advantage of this formalism is that it can be extended to magnetic textures with soft internal modes and does not rely on the usual rigid texture approximation. We first present the general formalism and apply to it to the known example of the translational modes of rigid skyrmions. Then we study the circular internal modes of skyrmions and antiskyrmions that are stabilized by anisotropic Dzyaloshinskii-Moriya interactions, and finally the gyration modes of skyrmions and antiskyrmions.

MA 52.40 Thu 15:00 Poster C

Skyrmion bubbles generation with oblique magnetic field and electrical currents — Sören Nielsen[1], •Enno Lage[1], Christian Denker[2], Markus Münzenberg[2], and Jeffrey McCord[1] — [1]Nanoscale Magnetic Materials - Magnetic Domains, Institute for Materials Science, Universität Kiel, Germany — [2]Institut für Physik, Universität Greifswald, Germany

Room temperature magnetic skyrmion bubbles have been found in Ta/CoFeB/TaO_x and similar systems comprising heavy metal/ferromagnet/oxide layers. Ta/CoFeB/MgO is a promising system presumably allowing for successful skyrmion bubble generation and detection by magnetic tunnel junctions (MTJ) with high TMR ratios. In this work, typical MTJ bottom electrodes and barriers (5 nm Ta/x CoFeB/3 nm MgO) trilayers with an optional Ru capping, deposited by e-beam evaporation (MgO, Ru) and magnetron sputtering (Ta, CoFeB), were used for skyrmion generation. We will present our results on skyrmions. Skyrmions are observed by magneto-optically using magneto-optical Kerr effect microscopy. A transition from in-plane to out-of-plane magnetic anisotropy is found for a CoFeB thickness of $x \approx 1.4$ nm. The stability of skyrmion bubbles in proximity of the transitional regime was found to cover an increased field range with increasing film thicknesses. Paths for the enhanced generation of skyrmion bubbles in thinner magnetic films based on the application of combined out-of-plane bias fields and in-plane magnetic field pulses will be demonstrated. We will further discuss the interaction of skyrmion bubbles with electrical currents.

MA 52.41 Thu 15:00 Poster C

Current-Induced Skyrmion Generation Through Morphological Phase Transitions in Chiral Ferromagnetic Heterostructures — Ivan Lemesh[1], Kai Litzius[2,3,4], Pedram Bassirian[2], •Nico Kerber[2,3], Daniel Heinze[2], Jakub Zazvorka[2], Felix Büttner[1], Lucas Caretta[1], Max Mann[1], Markus Weigand[4], Simone Finizio[5], Jörg Raabe[5], Mi-Young Im[6,7], Mathias Kläui[2,3], and Geoffrey S. D. Beach[1] — [1]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA — [2]Institut für Physik, Johannes Gutenberg-University, 55128 Mainz, Germany — [3]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [4]Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany — [5]Swiss Light Source, Paul Scherrer Institut, Villigen PSI CH-5232, Switzerland — [6]Center for X-ray Optics, Lawrence Berkeley National Laboratory, Berkeley, California 94720, USA — [7]Department of Emerging Materials Science, DGIST, Daegu 42988, Korea

The creation and current driven motion of magnetic skyrmions at room temperature was recently observed [1], but the key formation mechanisms are poorly understood. Here we show that in thin films pulsed currents can drive morphological phase transitions. Using high-resolution x-ray microscopy, we image the evolution of the spin texture with temperature and magnetic field, and demonstrate that transient Joule heating can drive the system across the stripe-skyrmion phase boundary. [1] Litzius, K. et al. Nat. Phys. 13, 170-175 (2017)

MA 52.42 Thu 15:00 Poster C

Impact of transition metals clusters on the stability and dynamics of Skyrmions — •I Gede Arjana, Jonathan Chico, Imara L. Fernandes, and Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany

Owing to their topological properties, magnetic skyrmions are prime candidates for future spintronic devices. However, incorporating them as possible bits of information hinges on their interaction with inhomogenities present in any device. Recently, single skyrmions in Pd/Fe/Ir(111) were moved using a Co trimer deposited on the surface but not with a single Co adatom[1]. Following our previous works [2,3], we investigate the interaction of $3d$ and $4d$ clusters with a single magnetic skyrmion in Pd/Fe/Ir(111) and explore their electronic and magnetic properties with a full *ab initio* approach. The latter is used in conjunction with atomistic spin dynamics to study the complex motion of skyrmions going beyond the description based on the Thiele equation. This allows us to study the effect that different types of clusters have over the skyrmions dynamics, and how such defects can be used to engineer tracks and nucleations areas, which are of importance for spintronic devices. – Funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme (ERC-consolidator grant 681405 - DYNASORE).

[1] C. Hanneken *et al.*, New J. of Physics, **18**, 055009 (2016).
[2] D. M. Crum *et al.*, Nat. Comms. **6**, 8541 (2015).
[3] I. L. Fernandes *et al.*, submitted (2017).

MA 52.43 Thu 15:00 Poster C

Thermal formation of skyrmion and antiskyrmion density — •Marie Böttcher[1,2,3], Stefan Heinze[2], Jairo Sinova[1,4], and Bertrand Dupé[1,2] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, 55099 Mainz, Germany — [2]Institute of Theoretical Physics and Astrophysics, University of Kiel, 24098 Kiel, Germany — [3]Graduate School Materials Science in Mainz, 55128 Mainz, Germany — [4]Institute of Physics, Academy of Sciences of the Czech Republic, Cukrovarnická 10, 162 53 Praha 6, Czech Republic

We use an atomistic extended Heisenberg model derived from density functional theory calculations [1] for the ultra-thin film system Pd/Fe/Ir(111) to show that temperature induces non-zero skyrmion and antiskyrmion densities. The parallel tempering Monte Carlo method is applied in order to reliably compute the B-T phase diagram in the presence of frustrated interactions and we introduce the topological susceptibility to evaluate the critical temperatures. The frustration of the exchange interaction turns out to have a crucial influence on the critical temperatures [2]. Here, we focus on the effect of the frustration of exchange interaction on the creation of skyrmions and antiskyrmions densities as a function of temperature and magnetic field.

[1] S. von Malottki *et al.*, Sci. Rep. **7**, 12299 (2017). [2] M. Böttcher *et al.*, *arXiv*:1707.01708 (2017).

MA 52.44 Thu 15:00 Poster C

Spin currents and triplet exciton condensate in magnetic field — •Dominique Geffroy[1,2], Atsushi Hariki[2], and Jan Kuneš[2,3] — [1]Department of Condensed Matter Physics, Faculty of Science, Masaryk University, Kolářská 2, 611 37 Brno, Czech Republic — [2]Institute of Solid State Physics, TU Wien, Wiedner Hauptstr . 8, 1020 Vienna, Austria — [3]Institute of Physics, the Czech Academy of Sciences, Na Slovance 2, 182 21 Praha 8, Czech Republic

We investigate spin-triplet exciton condensation in the two-orbital Hubbard model by means of dynamical mean-field theory. Employing an impurity solver that handles complex off-diagonal hybridization functions, we study the behavior of excitonic condensate in stoichiometric and doped systems subject to external magnetic field. We find a general tendency of the triplet order parameter to lay perpendicular to the applied field and identify exceptions from this rule. For solutions exhibiting odd-k spin textures, we discuss the Bloch theorem which, in the absence of spin-orbit coupling, forbids the appearance of spontaneous net spin current. We demonstrate that the Bloch theorem is not obeyed by the dynamical mean-field theory.

MA 52.45 Thu 15:00 Poster C

Towards understanding strong electron correlation in molecular complexes on surfaces — •Marc Philipp Bahlke and Carmen Herrmann — Institute for Inorganic and Applied Chemistry, University of Hamburg, Martin-Luther-King-Platz 6, 20146 Hamburg, Germany

The interaction of conduction band electrons with localized unpaired electrons can cause the formation of a singlet state at sufficiently low temperature. This effect is known as the Kondo effect and can be observed in many experimental setups such as break junctions and in scanning tunneling microscopy (STM) experiments.

Our goal is to understand the Kondo effect from a chemical perspective, to allow for a systematic manipulation of molecules (e.g. via ligand substitution) that in turn controls the Kondo effect. As a first step in this direction, we investigated a series of cobaltcarbonyl complexes adsorbed on Cu(100), as reported by P. Wahl *et al.* [1], concerning the Kondo effect in the scope of a combination of density functional theory and the single impurity Anderson model (DFT++).

We found that hybridization of the Co 3*d* shell strongly depends on the number of CO ligands attached to cobalt, which is potentially the reason for the increasing Kondo temperature with an increased number of Co ligands.

[1] P. Wahl, L. Diekhöner, G. Wittich, L. Vitali, M. A. Schneider, K. Kern, *Phys. Rev. Lett.* **95**, 166601 (2005).

MA 52.46 Thu 15:00 Poster C

Existence of noncollinear spin-spiral solutions of the Kohn-Sham equations for the homogeneous electron gas — •Maximilian Kulke and Arno Schindlmayr — Department Physik, Universität Paderborn, 33095 Paderborn, Germany

A spiral spin-density wave (SSDW) denotes a nonlinear magnetic configuration where the magnetization vector rotates helically around the spin-quantization axis. Such configurations are known to occur in the ground state of certain noncollinear magnetic materials, such as γ-Fe, but are also commonly studied in the frozen-magnon approximation for spin-wave excitations. Within spin-density-functional theory, SSDWs are occasionally difficult to identify due to the additional degrees of freedom, however. Here we study self-consistent spin-spiral solutions of the Kohn-Sham equations for the homogeneous electron gas with standard methods typically employed for real materials. The homogeneous electron gas allows a largely analytic treatment that avoids numerical inaccuracies affecting implementations for real materials. We use a local-spin-density functional and consider a variety of electron densities and wave vectors for the static planar helical variation of the magnetization. Our results show that noncollinear spin-spiral solutions do not exist for all parameter combinations but only for sufficiently small wave vectors, and that there are multiple solutions in some areas of the parameter space.

MA 52.47 Thu 15:00 Poster C

Magnetic Phases in Ni-Mn Heusler Alloys: A Case for Ab-initio Plus Structure Factor Calculations — •Marianne Schröter, Jan Büddefeld, Maurice Thomalzig, Alfred Hucht, and Anna Grünebohm — Universität Duisburg-Essen, Germany

Ni-Mn based magnetic Heusler alloys, which are among the candidates for environmentally friendly solid state cooling, show rich magnetic phase diagrams.[1] Competing ferromagnetic and anti-ferromagnetic interactions generate complicated spin structures, including different kinds of ferrimagnetic and helimagnetic ordering. To analyse these structures we augment the multi-step approach [2] (DFT and classical Heisenberg model with long-range magnetic interactions parametrized by DFT) by evaluating the magnetic structure factor.

We present temperature and concentration dependent magnetic phase diagrams for Ni(Co)Mn(Ga, Sn) alloys.

[1] T. Graf, et. al, Prog. Solid State Chem. 39, 1 (2011)
[2] D. Comtesse et .al., Eur. Phys. B 85, 343 (2012)

MA 52.48 Thu 15:00 Poster C

Growth of ferroelectric $BaTiO_3$ thin films on top of a ferromagnetic $La_{0.7}Sr_{0.3}MnO_3$ layer deposited on (001)-oriented $SrTiO_3$ substrate using pulsed laser deposition (PLD) — •Kevin Lancaster, Camillo Ballani, Christoph Hauser, Christian Eisenschmidt, and Georg Schmidt — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle

The investigation of the tunnelling anisotropic magnetoresistance (TAMR) demands well defined and homogeneous layers of a ferromagnet and a tunnelling barrier [1], ideally grown epitaxially on top of each other. A ferroelectric barrier like $BaTiO_3$ might add additional functionality to TAMR devices. Previous work [2] indicates the discrepancy between a decrease in surface roughness and in-plane tension for $BaTiO_3$ layers thicker than 5 nm on $La_{0.7}Sr_{0.3}MnO_3$ but an ideal tunnelling thickness of less than 4 nm. We present an optimization for thin film pulsed laser deposition of $BaTiO_3$ onto $La_{0.7}Sr_{0.3}MnO_3$ on (001)-oriented $SrTiO_3$ substrates and its characterization by the means of x-ray refraction and deflection, and conductive atomic force microscopy.

[1] J. D. Burton, E. Y. Tsymbal: "Tunneling anisotropic magnetoresistance in a magnetic tunnel junction with half-metallic electrodes", Phys. Rev. B93, 024419, 2016
[2] D. Hansen, R. Plunnecke: "Growth and Strain Relations in (001)-oriented Ferroelectric and Ferromagnetic Perovskite Oxide Thin Films", Institutt for elektronikk og telekommunikasjon, 2013

MA 52.49 Thu 15:00 Poster C

IrMnGa as candidate for a fully compensated ferrimagnet — •Johannes Kroder, Enke Liu, Gerhard H. Fecher, and Claudia Felser — Max Planck Institut CPfS, Dresden, Germany

Zero net magnetization and the absence of stray fields make antiferromagnets promising candidates for spintronics applications. Conventional antiferromagnets however have an identical electronic structure for both spin directions and therefore cannot carry any spin polarized current. An interesting alternative are fully compensated ferrimagnets (FC FiM) which consist of two antiferromagnetically coupled sublattices of different atomic species that cancel to a zero net magnetization. Due to the different sublattices FC FiM can be spin polarized, which was recently confirmed for Mn_2Ru_xGa [1] and for $Mn_{1.5}V_{0.5}FeAl$ [2].

In general, full- and half-Heusler compounds are a promising material class to search for new FC FiM since they often show half metallicity. Here we report on the cubic half-Heusler compound IrMnGa. Powder X-ray diffraction reveal a B32a-type structure where manganese occupies two different crystallographic sites which are coupled antiferromagnetically. VSM measurements and DFT calculations indicate that IrMnGa is not fully compensated but has a small residual moment. Moreover, we show that the magnetization can be significantly reduced by varying the composition which makes off-stoichiometric IrMnGa an interesting candidate as FC FiM.

[1] H. Kurt *et.al*, PRL **112**, 027201 (2014); [2] R. Stinshoff *et.al*, PRB **95**, 060410(R) (2017)

MA 52.50 Thu 15:00 Poster C

Electronic structure of high-TMR off-stoichiometric Co_2(Mn,Fe)Si Heusler thin films explored by hard X-ray photoelectron spectroscopy — •Siham Ouardi[1], Kidist Moges[2], Bing Hu[2], Gerhard H. Fecher[3], Masafumi Yamamoto[2], Tetsuya Uemura[2], Shigenori Ueda[4], and Claudia Felser[3] — [1]WPI Ad-vanced Institute for Materials Research, Tohoku University, Sendai 980-8577, Japan — [2]Graduate School of Information Science and Technology, Hokkaido University, Sapporo 060-0814, Japan — [3]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [4]National Institute for Materials Science, SPring-8, Hyogo, Japan

The quaternary Heuslers alloy Co_2(Mn,Fe)Si are among the most promising half-metallic ferromagnets and suitable as a spin source for spintronic devices. A giant tunneling magnetoresistance (TMR) ratio up to 2610% at 4.2 K (429% at 290 K) was realized on Co_2(Mn,Fe)Si/MgO/Co_2(Mn,Fe)Si magnetic tunnel junctions (MTJs) with Mn-rich, lightly Fe-doped Co_2(Mn,Fe)Si electrodes [1]. This work reports on the investigation of the electronic states of off-stoichiometric Co_2(Mn,Fe)Si Heusler thin films by hard X-ray photoelectron spectroscopy in combination with band structure calculations. Co, Fe, and Mn states are probed by magnetic dichroism in angle-resolved photoelectron spectroscopy at the 2*p* core levels. The effect of the Fe doping, as well as the antisite disorder on the valence states at the Fermi edge will be discussed.

[1] K. Moges, et al. Phys. Rev. B 93, 134403 (2016).

MA 52.51 Thu 15:00 Poster C

Magnetism and electric transport in Heusler compounds $Co_2V_{1-x}Cr_xGa$ — •Jörn Bannies, Johannes Kroder, Gerhard H. Fecher, and Claudia Felser — Max Planck Institut CPfS, Dresden, Germany

During the last decades Heusler compounds have attracted much interest due to their huge variety of properties. Among them the half-metallic ferromagnetism has been intensively investigated. Characteristically the saturation magnetization in half-metallic ferromagnets such as Co_2 based Heusler compounds scales linearly with the valence electron count which is known as the Slater Pauling rule.

Recently Co_2 based Heusler compounds have been proposed to host Weyl fermions. The anomalous Hall effect is assumed to be maximized when the Weyl nodes reside at the Fermi level. Thus, shifting the Weyl nodes around the Fermi level can be used to verify this assumption. Due to the large compositional variability provided by Heusler compounds this is easily be achieved by substitutional alloying.

Here we report on the Heusler system $Co_2V_{1-x}Cr_xGa$. Substitution of V by Cr is intended to shift the Weyl nodes to higher energies passing through the Fermi level, thereby generating a maximum in the anomalous Hall conductivity. This is expected to occur at $x \approx 0.5$. Polycrystalline samples with x ranging from 0 to 1 were prepared by conventional arc melting technique. After annealing, the magnetisation followed obey the Slater Pauling rule which hints on their half-metallicity. Additionally temperature dependent measurements of the magnetoresistivity were carried out.

MA 52.52 Thu 15:00 Poster C

Growth, Structure, and Properties of La2MBO6 (M = Co, Ni, Mg, and Zn; B = Ru, Ir) Double Perovskite Single Crystals — •Ryan Morrow[1], Mihai Sturza[1], Laura T. Corredor[3], Michael Vogl[1], Anja Wolter-Giraud[1], Sabine Wurmehl[1,2], and Bernd Büchner[1,2] — [1]Leibniz Institute for Solid State and Materials Research Dresden IFW, Dresden D-01069, Germany — [2]Institute for Solid State Physics, Technische Universität Dresden, Dresden D-01069, Germany — [3]Universidade Federal do Rio Grande do Norte, Natal-RN 59078-970, Brazil

Double perovskites have received a great deal of attention in recent times due to their magnetic properties. However, the vast majority of experimental data thus far in this field has been generated with powder samples resulting in numerous open questions concerning the underlying principles governing the magnetic properties of these complex oxides. Here it is shown that, using a flux method, double perovskite iridate single crystals as large as 3 mm with formula La2MBO6 (M = Co, Ni, Mg, and Zn; B = Ru, Ir) have been grown. The structure and properties of the crystals are characterized and are in agreement with previous powder data. Therefore, future more detailed experiments will be possible on a variety of double perovskite single crystals with numerous electronic configurations.

MA 52.53 Thu 15:00 Poster C

Anti-site disorder induced diluted magnetism in semiconducting CoFeTiAl alloy — •tingting lin — Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany

The ordered CoFeTiAl Heusler compound shows a semiconducting character and has been synthesized. However, the detailed electronic structure and the effect of anti-site disorder, which prevails in such type of materials, are unclear. We investigated the effect of anti-site disorder on the electronic structure using the KKR-CPA method, and found that the Co-Ti and Fe-Ti anti-site disordering can induce diluted magnetism in CoFeTiAl alloy. For instance, the Fe-Ti anti-site disorder can induce a 100% spin polarization at the Fermi level within a specific range of disorder parameters. The Co-Fe anti-site disorder occurs more easily judging by the total energies, but has little effect on the semiconductor behavior in the electronic structure and magnetic properties. Detailed analysis reveals that the magnetism can be attributed to the contributions of Co, Fe, and Ti atoms on the anti-site disordered sites, i.e., the diluted magnetism in CoFeTiAl alloy is induced by the anti-site disorder rather than by introducing magnetic dopant elements. This makes the system interesting for future spintronic applications.

MA 52.54 Thu 15:00 Poster C

Magnetoelectronic structure of ultrathin $Fe_3O_4/SrTiO_3$ heterointerfaces — •Mai Hussein Hamed[1], Ronja Anika Heinen[1], Marek Wilhem[1], Patrick Lömker[1], Carolin Schmitz-Antoniak[1], Andrei Gloskovsky[2], Wolfgang Drube[2], Claus M. Schneider[1,3], and Martina Müller[1,4] — [1]Peter-Grünberg-Institut (PGI-6), Forschungszentrum Jülich GmbH, Germany. — [2]Photon Science, DESY, Hamburg, Germany. — [3]Fakultät für Physik, Universität Duisburg-Essen, Germany. — [4]Experimentelle Physik I, Technische Universität Dortmund, Germany.

$Fe_3O_4/SrTiO_3$ heterostructures are promising candidates for oxide spintronics, as their functionality depends strongly on the interface properties. For this purpose, we emphasized on the impact of reduces dimensionality on the magnetoelectronic and structural properties of ultrathin magnetite.

Magnetite thin films are grown epitaxially on Nb-$SrTiO_3$(001) substrates via pulsed laser deposition with varying thicknesses (d=2-38nm). By magnetic characterization, it is found for ultrathin Fe_3O_4 coverages (d=2nm) that the saturation magnetization M_S reduces to $1\mu_B$/f.u and the Verwey transition shifts towards lower value T_V=20K instead of $4\mu_B$/f.u and 120K for bulk Fe_3O_4 respectively. Using HAXPES and XMCD techniques provides complementary element-selective information of the surface and buried interface magnetoelectronic structure. Our results suggest the formation of a 2ML γ-Fe_2O_3 intralayer at the interfaces. Interfacial redox reaction or oxygen mobility could account for the formation of this intralayer phase.

MA 52.55 Thu 15:00 Poster C

MBE growth of I-Mn-V antiferromagnets — •Martin Brajer[1,2], Štěpán Svoboda[1], Richard Campion[3], and Vít Novák[1] — [1]Institute of Physics ASCR, v.v.i., Cukrovarnicka 10, 162 53 Praha, Czech Republic — [2]Faculty of Mathematics and Physics, Charles University in Prague, Ke Karlovu 3, 121 16 Prague, Czech Republic — [3]School of Physics and Astronomy, University of Nottingham, UK

We report on growth of two members of the I-Mn-V family of room-temperature antiferromagnets (AFs) by means of molecular beam epitaxy: tetragonal phase CuMnAs and LiMnAs. The former is an AF semimetal with broken inversion symmetry, allowing for current-induced switching of AF moments. It can be successfully grown on standard zinc-blende semiconductor substrates GaAs, GaP and Si. We study strain relaxation and surface morphology of the material depending on the type of the substrate used. The latter is tetragonal LiMnAs, an AF semiconductor with band-gap of 1.6 eV. It can be grown on a lattice-matched InAs substrate, which allows for a stable 2D growth, but hinders its basic transport characterization because of the high substrate conductivity. We attempt to overcome this problem by using a thin metamorphic (Ga,In)As layer on top of an insulating GaAs substrate. This approach brings about a problem of strain relaxation and related surface morphology degradation: the thinner the metamorphic layer (i.e. the lower its conductance), the higher the density of misfit dislocations, calling for a compromise between the suppression of the parasitic conductivity and enhanced surface roughness.

MA 52.56 Thu 15:00 Poster C

Band-gap evolution of thin ferromagnetic europium-oxide films at low temperatures — •Marcel Ney[1], Günther Prinz[1], Patrick Lömker[2], Martina Müller[2,3], and Axel Lorke[1] — [1]Faculty of Physics, Universität Duisburg-Essen, D-47048 Duisburg — [2]Peter Grünberg Institut, Forschungszentrum Jülich GmbH, D-52428 Jülich — [3]Faculty of Physics, TU Dortmund, D-44227 Dortmund

In spintronic research, materials with magnetic properties, which can be used as spin filters, are of particular interest. We are investigating EuO with a Curie temperature of $T_C = 69$K, as one candidate for this application. It is of interest to study how the ferromagnetic phase transition below T_C affects the optical band-gap of EuO.

Thin EuO-layers were grown by molecular-beam-epitaxy on YSZ substrates, with different thicknesses. A FTIR-spectrometer, was used to measure the transmission through the EuO thin films to determine the optical band-gap energy.

The EuO-films with thicknesses between 5nm and 30nm were investigated in a range of 293K down to 25K. At room temperature, we observe a dependence of the band-gap on the layer thickness due to the quantum confinement effect. When cooling a 20nm layer below the Curie temperature, we observe a red shift of the optical band-gap of about $E_a = 0.27 \pm 0.02$eV. This energy shift is in good agreement with theoretical and experimental values for EuO exchange splitting effects. For thin films first measurements show a different temperature dependent behavior upon cooling below T_C, which indicates that quantum size effects will influence the magnetic ordering of the material.

MA 52.57 Thu 15:00 Poster C

Synthesis, Structure and Magnetic Properties of the AB3Si2Sn7O16 Phases — •Morgan Allison[1,2,3], Siegbert Schmid[2], Tilo Söhnel[3], Glen Stewart[4], Christopher Ling[1], and Sabine Wurmehl[1] — [1]IFW, Dresden, Germany — [2]School of Chemistry, The University of Sydney, Sydney, Australia — [3]School of Chemistry, The University of Auckland, Auckland, New Zealand — [4]School of PEMS, UNSW@ADFA, Canberra, Australia

Layered oxide structures have been reported to exhibit several novel magnetic material properties. Transition metal oxide materials with mixtures of different elements have also been shown to exhibit several useful magnetic behaviours, many of which could be extremely beneficial for future technical devices. Fe4Si2Sn7O16 provides a novel situation in oxide compounds. It can be described as a composite of oxygen linked intermetallic (FeSn6) octahedra and (FeO6)/(SnO6) kagomé-oxide layers within the one structure. SiO4 tetrahedra separate these layers which leads to electronic isolation of the repeated layers by about 7 Å, resulting in a nearly perfectly 2D oxide system. In our investigation, doping experiments across a range of different transition metal chemistries were performed, refinements of the structures from X-ray and neutron powder diffraction patterns were used to determine the crystal structure and distribution of transition metals across both layers. In this presentation the results of different elemental substitution on the crystal and magnetic structures of this family of compounds will be discussed, additionally we will present some of the novel results from the spectroscopic and magnetic characterisation of these materials.

MA 52.58 Thu 15:00 Poster C

Inelastic electron tunneling spectroscopy at tunnel junctions with integrated topological material — •Denis Dyck[1], Robin-Pierre Klett[1], Andreas Becker[1], Jan Haskenhoff[1], Jan Krieft[1], Karsten Rott[1], Torsten Hübner[1], Gregor Mussler[2], Jan-Michael Schmalhorst[1], Andreas Hütten[1], and Günter Reiss[1] — [1]Center for Spinelectronic Materials and Devices, Physics Department, Bielefeld University, Bielefeld, Germany — [2]Forschungszentrum Jülich, Peter-Grünberg Institut, Jülich, Germany

The research on topological insulators is evolving rapidly. Within less than a decade, experimental effort led from fundamental material analysis to first real topological devices exploiting physics for future spintronic applications. However, all data were taken at planar devices. For technical integration into applicable information architecture, devices based on vertical transport are required to achieve, e.g., scalability and low power consumption. Here, the successful patterning and integration of tunnel junctions based on topological back electrodes are a necessary way to go. Furthermore, different classes of topological matter are investigated: topological crystalline insulators, represented by SnTe thin films, BiSbTe as a topological insulator and Co2TiSi as a magnetic Weyl semimetal. In this work we report on the realization of such tunnel junctions consisting of aforementioned materials and their characterization using inelastic electron tunneling spectroscopy (IETS). Different excitations for different topological materials can be identified.

MA 52.59 Thu 15:00 Poster C

Impact of ultrafast transport on the high-energy states of a photoexcited topological insulator — •Friedrich Freyse[1], Marco Battiato[2], Andrei Varykhalov[1], Oliver Rader[1], and Jaime Sánchez-Barriga[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Elektronenspeicherring BESSY II, Albert-Einstein-Str. 15, 12489 Berlin, Germany — [2]Institute of Solid State Physics, Vienna University of Technology, Vienna A-1040, Austria

Ultrafast dynamics in three-dimensional topological insulators (TIs) opens new routes for increasing the speed of information transport up to frequencies thousand times faster than in modern electronics. However, up to date, disentangling the exact contributions from bulk and surface transport in the subpicosecond dynamics of these materials remains a difficult challenge. Here, using time- and angle-resolved photoemission, we demonstrate that driving a TI into the bulk insulating regime opens new channels for ultrafast transport on the surface that unexpectedly persist up to high energies above the Fermi level. In particular, we show that the emergent transport channels are due to an ultrafast process of surface charge accumulation that is directly connected to the existence of a projected bulk band gap at high energy and the lack of available bulk states at the Fermi level. We further provide a qualitative description of the mechanisms responsible for the observed electron dynamics.

MA 52.60 Thu 15:00 Poster C

Characterizing Magnetoelectricity at the Local Scale — •Harsh Trivedi[1], Vladimir Shvartsman[1], Robert Pullar[2], Marco Medeiros[2], Pavel Zelenovskiy[3], Vladimir Shur[3], and Doru Lupascu[1] — [1]Institute for Materials Science and Centre for Nanointegration Duisburg-Essen (CeNIDE), University of Duisburg-Essen, 45141, Essen, Germany — [2]CICECO, University of Aveiro, 3810-193, Aveiro, Portugal — [3]School of Natural Sciences and Mathemaics, Ural Federal University, 620002, Ekaterinburg, Russia

A growing interest in studying local manifestations of macroscopic functionalities has led to a wide spread development in near-field microscopic techniques. Common examples of such studies include electrical conduction at ferroelectric/ferroelastic domain walls, polarization dynamics in ferroelectrics, study of ergodicity in relaxor-ferroelectrics, and the local magnetoelectric (ME) effect. The data in these studies are often captured in the form of sequence of images or spectroscopic responses over a 2D-grid. Theoretically, the effect under consideration can be characterized by local measurement of the induced parameters. However, there are certain instrumental challenges. In this poster we highlight these challenges by considering composite multiferroics as a case study. Here, we consider local measurements on various BaTiO3/Ferrite based composite systems. We have utilized techniques like Piezoresponse Force Microscopy (PFM), Confocal Raman Microscopy (CRM), Magnetic Force Microscopy (MFM) for the local measurements. To overcome the above-mentioned challenges, we propose a set of approximation methods based on machine-learning.

MA 52.61 Thu 15:00 Poster C

Impact of low temperature, high pressure and illumination wavelength on photo-induced effects in $BiFeO_3$ by means of optical spectroscopy — •Fabian Meggle[1], Jihaan Ebad Allah[1], Michel Viret[2], Jens Kreisel[3], and Christine Kuntscher[1] — [1]Experimentalphysik II, Universität Augsburg, D-86159 Augsburg, Germany — [2]Service de Physique de l'Etat Condensé, CEA Saclay, DSM/IRAMIS/SPEC, URA CNRS 2464, 91191 Gif-Sur-Yvette Cedex, France — [3]Materials Research and Technology Department, Luxembourg Institute of Science and Technology, L-4422 Belvaux, Luxembourg

Recently, it has been reported that during illumination with green light $BiFeO_3$ crystals show three absorption features in the optical spectrum between 1.0 and 2.2 eV [1]. We studied the impact of low temperature, high pressure, and illumination wavelength on this photo-induced effect by using optical spectroscopy. Our findings will be discussed in terms of the photostriction effect observed in $BiFeO_3$ [2].

[1] F. Burkert et al., Appl. Phys. Lett. **109**, 182903 (2016)
[2] B. Kundys et al., Nat. Mater. **9**, 803 (2010)

MA 52.62 Thu 15:00 Poster C

low-temperature magnetoelectric effect in multiferroic h-Yb1-xHoxMnO3 — •gang qiang[1], yifei fang[2], and jincang zhang[2] — [1]Experimentelle Physik 2, Technische Universitat Dortmund, 44221 Dortmund, Germany — [2]Materials Genome Institute and Department of Physics, Shanghai University, Shanghai 200444, China

Hexagonal RMnO3 as a group of important multiferroic materials, attracted much attention during the last few decades. Much work, by now, has been done on their magnetic structure, magnetic phase diagrams as well as the high temperature ferroelectric transition, but few investigation has been carried out to study the low-temperature ferroelectric properties nor its interaction with the magnetic transitions. In this work, we carried out a detailed study of the low-temperature ferroelectricity, magnetic property as well as the ME effect in bulk Yb1-xHoxMnO3 ($0<=x<=0.6$, $\Delta x=0.2$). In h-YbMnO3 (x=0), ferroelectric polarization is found around 43.5 K and is supposed to be closely related with the structure change, and defects in the material is supposed to be responsible for the asymmetry of the P-T curves under opposite poling filed. In the Ho-doped samples ($x>0$), two-dimensional antiferromagnetic (AFM) perturbation as well as the second AFM ordering are observed. Substitution of Yb by Ho atoms shows great influences on the electric property and the low-doping concentration tend to be more favorable for the enhancement of electric polarization.

MA 52.63 Thu 15:00 Poster C

Exchange coupling in multiferroics/ferromagnet heterostructures — •Sven Becker, Mehran Vafaee, Mathias Kläui, and Gerhard Jakob — Institute of Physics, Johannes Gutenberg University Mainz, 55099 Mainz, Germany

The interface between the antiferromagnetic perovskite $BiFeO_3$ and a ferromagnet has been target of numerous research projects. The interlayer exchange coupling was often weak at room temperature[1] or died after some time because of oxidation of the interface[2]. Multiferroic $Bi_{1-x}Ba_xFeO_3$/ferromagnet (x=0, 0.15) as well as $TmFeO_3$/ferromagnet heterostructures have been fabricated using pulsed laser deposition (PLD). As ferromagnetic layers $La_{0.7}Sr_{0.3}MnO_3$ and ferrimagnetic Sr_2FeMoO_6 have been deposited. Single crystal growth has been confirmed using XRD. Ferroelectric properties of $Bi_{0.85}Ba_{0.15}FeO_3$ have been proven by piezoresponse force microscopy (PFM). Heterostructures have been investigated with regard to the exchange coupling using a SQUID magnetometer. [1] M. Vafaee Appl. Phys. Lett. **108**, 072401 (2016) [2] J. T. Heron, Nature **516**, 370 (2014)

MA 52.64 Thu 15:00 Poster C

Voltage control of magnetism in oxide heterostructures: A

combined scattering and electron microscopy investigation — •Tanvi Bhatnagar[1], Anirban Sarkar[1], Markus Waschk[1], Emmanuel Kentzinger[1], Andras Kovacs[2], Rafal Dunin-Borkowski[2], and Thomas Brückel[1,3] — [1]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science (JCNS-2) and Peter Grünberg Institut (PGI-4), JARA-FIT 52425 Jülich, Germany — [2]Ernst Ruska-Centre for Microscopy and Spectroscopy with Electrons and Peter Grünberg Institute, Forschungszentrum Jülich GmbH, 52425 Jülich, Germany — [3]Forschungszentrum Jülich GmbH, Jülich Centre for Neutron Science at MLZ, Lichtenbergstr. 1, 85784 Garching, Germany

The voltage control of magnetism in oxide heterostructures e.g. LaxSr1-xMnO3/BaTiO3 has drawn a considerable interest due to strong couplings between lattice, charge, spin and orbital degrees of freedom at the interfaces and for improving the functionality of future spintronic devices. Here, we use advanced deposition techniques (including oxide molecular beam epitaxy) and investigate the chemical and magnetic structure of the resulting interfaces as a function of electric field. For this investigation, we make use of a combination of advanced scattering (neutron and X-ray) methods and electron microscopy and spectroscopy (including off-axis electron holography and electron magnetic circular dichroism).

MA 52.65 Thu 15:00 Poster C

Exploring magnetoelectricity at the nanoscale in two-phase hetero-structured multiferroic thin films — •Muhammad Naveed-Ul-Haq[1], Vladimir Shvartsman[1], Harsh Trivedi[1], Samira Webers[2], Heiko Wende[2], and Doru Lupascu[1] — [1]Institute for Materials Science and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg- Essen, Universitätsstraße 15, 45141 Essen, Germany. — [2]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, Lotharstraße 1, 47057 Duisburg, Germany.

High quality epitaxial bi-layered $CoFe_2O_4 - BaTiO_3$ thin films were prepared on $SrTiO_3 : Nb(100)$ and $SrTiO_3 : Nb(111)$ substrates using pulsed laser deposition. X-ray diffraction and transmission electron microscopy showed that the films are polycrystalline single-phase perovskite, free of additional phases. Piezoforce response microscopy revealed that the film on $SrTiO_3 : Nb(111)$ substrate shows strong lateral and vertical PFM responses. However, the film on $SrTiO_3 : Nb(100)$ shows good response only in the lateral direction. The magnetoelectric properties were studied by applying an in-plane magnetic field and measuring the piezoresponse and a subsequent analysis via the principal components analysis (PCA). It was discovered that the thin films grown on $SrTiO_3 : Nb(111)$ substrate show a better strain mediated coupling than those grown on $SrTiO_3 : Nb(100)$ substrate. Thus it is concluded that the substrate orientation has a strong influence on the local piezoelectric and magnetoelectric properties of films.

MA 52.66 Thu 15:00 Poster C

Electric field control of chiral correlations above the multiferroic phase transition in $Ni_3V_2O_8$ — •Sebastian Biesenkamp[1], Jonas Stein[1], Karin Schmalzl[2], Navid Qureshi[3], and Markus Braden[1] — [1]Institute of Physics II, University of Cologne, Germany — [2]JCNS at ILL, Grenoble, France — [3]ILL, Grenoble, France

Multiferroics allow one to control chiral magnetic order by an electric field. While this effect is well established in the long-range multiferroic phase, only recently it was observed that in $TbMnO_3$ and in $MnWO_4$ chiral correlations can be controlled even above the onset of long-range multiferroic order [1]. Here we report polarized neutron scattering experiments on $Ni_3V_2O_8$ that reveal the qualitatively same behavior in a region above the transition to the multiferroic phase. Time-resolved neutron scattering experiments have been executed in order to resolve the relaxation time τ of chiral domains in $Ni_3V_2O_8$ for different temperatures, while switching them with external fields of about 1kV/mm. With our time-resolved setup, it was possible to follow the relaxation of chiral domains over 5 orders of magnitude in time, yielding a simple activation law $\tau \propto \exp(E_A/k_BT)$.

[1]Stein et al. Phys. Rev. Lett. 119, 177201 (2017)

MA 52.67 Thu 15:00 Poster C

Structural and magnetic properties of Ba2Mg0.4Co1.6Fe12O22 hexaferrites — •B. Georgieva[1], S. Kolev[1], K. Krezhov[2], Ch. Ghelev[1], B. Vertruyen[3], R. Closset[3], A. Mahmoud[3], R. Cloots[3], A. Zaleski[4], and T. Koutzarova[1] — [1]Institute of Electronics, Bulgarian Academy of Sciences, Sofia, Bulgaria — [2]Institute for Nuclear Research and Nuclear Energy, BAS, Sofia, Bulgaria — [3]Chemistry Department, University of Liege, Belgium — [4]Institute of Low Temperature and Structure Research, PAS, Wroclaw, Poland

In multiferroic materials, long-range magnetic and ferroelectric orders coexist resulting in a magnetoelectric effect. For example, Y-type hexaferrites, (as Ba2Mg2Fe12O22) have a relatively high temperature of magnetic transition (~200 K) to a spiral spin arrangement and an easy magnetization axis lying in a plane perpendicular to the c crystal axis. Multiferroicity exists without an external magnetic field, a longitudinal-conical spin arrangement arises below 50 K, and the direction of the electric polarization can be controlled by low magnetic fields (<0.02 T). We studied the effect of Co substitution in Ba2Mg2Fe12O22 on its structural and magnetic properties. Ba2Mg0.4Co1.6Fe12O22 powder was synthesized by sonochemical co-precipitation. Its XRD spectra had the characteristic peaks of the Y-type hexaferrite as a main phase. Less than 2% of CoFe2O4 appeared as a second phase; this was confirmed by Moessbauer spectroscopy. The magnetization at 50kOe was 30emu/g and 26.6emu/g at 4.2 K and 300 K. The ZFC and FC magnetization curves measured at 500 Oe showed a magnetic phase transition from a ferrimagnetic-to-helical spin order at 200 K.

MA 52.68 Thu 15:00 Poster C

Structural investigations on Erythrosiderite-type compounds — •Tobias Fröhlich[1], Ladislav Bohatý[2], Betra Becker[2], Arsen Gukasov[3], Martin Meven[4], and Markus Braden[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Kristallographie, Universität zu Köln — [3]Laboratoire Léon Brillouin, CEA-CNRS, CEA/Saclay — [4]Heinz-Maier-Leibnitz Zentrum, Technische Universität München

Erythrosiderite-type compounds of the form $A_2[FeCl_5(H_2O)]$ were discovered as being magneto-electric. We investigate the crystal and magnetic structures of the compounds $(NH_4)_2[FeCl_5(H_2O)]$ and $Cs_2[FeCl_5(H_2O)]$. In contrast to the other erythrosiderite-type compounds, $(NH_4)_2[FeCl_5(H_2O)]$ is multiferroic. We studied a structural phase transition occurring in this material well above the onset of magnetic order by single-crystal neutron diffraction. The structural transition can be attributed to the ordering of the NH_4 groups. The compound $Cs_2[FeCl_5(H_2O)]$ plays an exceptional role in this material family: It differs from the other erythrosiderite-type compounds with respect to its crystal structure. While most erythrosiderite-type compounds crystallize in space group *Pnma*, this compound exhibits space group *Cmcm* associated with a different arrangement of the $FeCl_5O$ octahedra. Again, there is a structural phase transition occuring well above the magnetic ordering that was neglected for most investigations so far. We investigated both compounds by neutron and X-ray diffraction and present an analysis of their low-temperature crystal structures and its consequences for the magneto-electric properties.

MA 52.69 Thu 15:00 Poster C

THz spectroscopy on chiral Ni_3TeO_6 in magnetic fields up to 8 T — •David Maluski[1], Malte Langenbach[1], David Szaller[2], István Kézsmárki[3], Joachim Hemberger[1], and Markus Grüninger[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Festkörperphysik, Technische Universität Wien — [3]Experimentalphysik V, Universität Augsburg

In the realm of multiferroicity, Ni_3TeO_6 stands out for the observation of non-hysteretic magnetic switching and the record linear magnetoelectric coupling constant in single-phase materials [1]. The structure of Ni_3TeO_6 is both chiral and polar already at room temperature. The antiferromagnetically ordered phase below $T_N = 53\,K$ features collinear ordered moments and a significantly enhanced electric polarization due to magneto-electric coupling [1]. In an external magnetic field, chiral structures show both natural optical activity as well as magnetic optical activity (Faraday effect). However, one may also expect more exotic effects such as magneto chiral dichroism or quadrochroism [2]. Circularly polarised light is particularly well suited to address such effects. We study the optical properties of Ni_3TeO_6 in the THz range using circularly polarised light, high magnetic fields, and low temperatures.

[1] Y. S. Oh *et al.*, Nat. Commun. 5:3201 (2014)
[2] I. Kézsmárki *et al.*, Nat. Commun. 5:3203 (2014)

MA 52.70 Thu 15:00 Poster C

Single crystal growth, magnetic phase diagram and antiferromagnetic resonance modes in $MTiO_3$ (M=Co,Ni) — •Kaustav Dey[1], Johannes Werner[1], Jakob Kaiser[1], Changhyun Koo[1], Rabrindranath Bay[2], Surjeet Singh[2], and Rüdiger Klingeler[1]

— [1]Kirchhoff Institute for Physics, Heidelberg University, Germany — [2]Indian Institute of Science Education and Research (IISER), Pune, India

Single crystals of layered $S = 1$ and $S = 3/2$ antiferromagnets $MTiO_3$ (M=Co,Ni) which both show pronounced magnetodielectric coupling have been grown by the optical floating-zone method. The single crystals have been studied by means of magnetometry up to 60 T and high-frequency electron spin resonance (HF-ESR). The magnetic phase diagrams are derived, including a broad field-induced anomaly indicative of spin-reorientation for $B||ab$-plane. For $NiTiO_3$, the reonance frequency vs. field diagram in the ordered state and the temperature dependence of the main resonance modes are presented. The antiferromagnetic resonance modes imply an easy plane-type anisotropy. Zero-field splitting of the out-of-plane modes amounts to 190 GHz and the gapped in-plane mode is consistent with the saturation field of $B_{ab} = 35$ T seen in the pulsed-field magnetisation studies. In $CoTiO_3$, the HF-ESR data are less clear but there is evidence for the easy-plane mode saturating at $B_{ab} = 16$ T with zero-field splitting well beyond the accessible frequency range of 1 THz.

MA 52.71 Thu 15:00 Poster C

Spin-wave transport and higher harmonic generation in Néel walls — •Kai Wagner[1,2], Olga Gladii[3], David Halley[3], Yves Henry[3], Matthieu Bailleul[3], Attila Kákay[1], and Helmut Schultheiss[1,2] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Institute of Ion Beam Physics and Materials Research, 01328 Dresden, Germany — [2]TU Dresden, 01307, Dresden, Germany — [3]Institut de physique et chimie des matériaux de Strasbourg, 67034 Strasbourg, France

Magnetic domain walls are promising candidates for flexible and reconfigurable waveguides in magnonic circuitry [1,2,3]. We investigate spin-wave transport along 90° Néel walls in microstructured thin-film elements made of Py as well as Fe [4] by μBLS [5] and via micromagnetic simulations [6]. The experiments cover the range from thermal excitation, through the linear regime up to non-linear excitation and higher harmonic generation associated with the excitation of previously not observed guided spin-wave modes. Additionally, first experimental observations of spin-wave transport along interconnected Néel walls in flux closure domain structures and along walls, which suddenly change their direction at the edge of the microstructure are presented.

References [1] D. Grundler, Nat. Phys., 11, 438-441 (2015). [2] F. Garcia-Sanchez et al., PRL, 114, 247206 (2015). [3] K. Wagner et al., Nature Nanotechnology, 11, 432-436 (2016). [4] O. Gladii et al., Phys. Rev. B 96, 174420 (2017). [5] T. Sebastian et al., Front. Phys., 3, 35 (2015). [6] A. Vansteenkiste et al., AIP Advances, 4, 107133 (2014).

MA 52.72 Thu 15:00 Poster C

Current driven domain wall creation in ferromagnetic nano-wires — •Nils Sommer[1], Matthias Sitte[1], Davi Rohe Rodrigues[2], and Karin Everschor-Sitte[1] — [1]Institute of Physics, Johannes Gutenberg Universität, 55128 Mainz, Germany — [2]Department of Physics & Astronomy, Texas A&M University, College Station, Texas 77843-4242, USA

A central topic in spintronics is the manipulation of magnetic textures by currents.

In a recent work, it was predicted that magnetic domain walls can be generated in ferromagnetic nano-wires by means of an electric current once there is an inhomogeneity.

In this work, the focus is on a set-up where the magnetization of the ferromagnetic wire was mainly aligned along the wire. Only the magnetization at one end of the wire was fixed along a perpendicular direction. It has been shown that above a certain threshold current density domain walls are injected into the nano-wire with a period that is controlled by the current strength.

During my Bachelor research, we have analysed the influence of the orientation of the fixed magnetization at the end of the wire. We have shown that while reducing the tilting angle the threshold current above which domain walls are shedded is increasing. Decreasing the tilting angle to zero we were able to recover the ferromagnetic instability.

MA 52.73 Thu 15:00 Poster C

Interaction of Domain Walls and Skyrmions — •Venkata Krishna Bharadwaj, Kyoung-Whan Kim, and Karin Everschor Sitte — Johannes Gutenberg Universität

Magnetic domain walls and skyrmions are promising candidates for spintronics applications such as racetrack memory devices. Motivated by recent experiments [1-3], we study the interactions between domain walls and skyrmions and their interplay in the presence of inhomogeneous current distributions. In the first step, we perform numerical simulations with Micromagnum [4] with some software extensions to analyze the production of different magnetic textures and the possibility to form skyrmions upon the collision of domain walls. [1] W.Jiang et al., Science 349, 283 (2015), [2] S. Woo. Et al, Nature Materials 15, 501 (2016) [3] S.Woo et al., Nature Physics 13, 448 (2017) [4] Micromagnum, http://micromagnum.informatik.uni-hamburg.de/

MA 53: General assembly of the Division of Magnetism (MA)

All members of the Division of Magnetism are invited to participate!

Time: Thursday 18:00–19:00 Location: H 0110

Approximate duration: 60 minutes

MA 54: Spin-dependent transport phenomena

Time: Friday 8:00–10:00 Location: EB 301

MA 54.1 Fri 8:00 EB 301

Spin-dependent electrical transport of Heusler alloys at nonzero temperatures from the first principles — •David Wagenknecht, Karel Carva, and Ilja Turek — Department of Condensed Matter Physics, Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Novel electrical and spintronic devices are required to operate at real-life conditions and to be reliable in a wide range of temperatures. Halfmetals are promising candidates for applications that manipulates with spin degrees of freedom and one of the most studied materials suitable for such usage are Heusler alloys.

We will present calculations of the electronic structure and electrical transport properties at nonzero temperatures of Heusler alloys like NiMnSb. The temperature-induced disorder, especially phonons, dramatically influence the properties. The approach is based on the fully relativistic tight-binding linear muffin-tin orbital (TB-LMTO) method with the coherent potential approximation (CPA) [1] and we will focus on the spin-dependent properties, e.g., electrical conductivity and spin-polarization [2].

The results will show a combined effect of the chemical, magnetic and temperature-induced disorder and a discussion of an efficiency of the spin-dependent transport for various disorders will be included. It may be used to design novel spintronic devices reliable at, e.g., room temperatures.

[1] K. Carva et al. Phys. Rev. B 73, 144421 (2006)

[2] D. Wagenknecht et al. Proc. SPIE 10357, 103572W (2017)

MA 54.2 Fri 8:15 EB 301

Perfect spin filter by periodic drive of a ferromagnetic quantum barrier — •Sebastian Eggert[1], Daniel Thuberg[2], Enrique Munoz[2], and Sebastian Reyes[2] — [1]TU Kaiserslautern and Research Center OPTIMAS — [2]Pont. Univ. Cat. de Chile, Santiago

We consider the problem of particle tunneling through a periodically driven ferromagnetic quantum barrier connected to two leads. The barrier is modeled by an impurity site representing a ferromagnetic layer or quantum dot in a tight-binding Hamiltonian with a local magnetic field and an AC-driven potential, which is solved using the Floquet formalism. Our results show that the time-periodic potential causes sharp resonances of perfect transmission and reflection, which can be tuned by the frequency, the driving strength, and the magnetic field. We demonstrate that a device based on this configuration could act as a highly-tunable spin valve for spintronic applications.

MA 54.3 Fri 8:30 EB 301

Current induced Néel-order switching in antiferromagnetic CuMnAs deposited by magnetron sputtering — •Tristan Matalla-Wagner, Jan-Michael Schmalhorst, Günter Reiss, and Markus Meinert — Center for Spinelectronic Materials and Devices, Bielefeld University, Germany

Antiferromagnets which fulfill certain symmetry properties allow for an intrinsic relativistic Néel-order spin-orbit torque (NSOT) driven by an electrical current [1]. The antiferromagnetically coupled sublattices of tetragonal CuMnAs are inversion partners and, thus, can experience a NSOT which can reorient the Néel vector $\boldsymbol{L}$ perpendicular to the applied charge current [2]. Therefore, this material is suitable to manufacture novel antiferromagnetic memory devices that are extraordinarily robust against external influences [3]. Here, we report on our experiments on the electrical switching of the Néel-order using short current pulses in highly oriented films of CuMnAs, deposited using dc-magnetron sputtering. Our findings corroborate the hypothesis of a thermally activated switching of $\boldsymbol{L}$ in CuMnAs, similar to the switching of sputtered Mn_2Au [4].

[1] J. Železný *et al.*, Phys. Rev. Lett. **113**, 157201 (2014)
[2] P. Wadley *et al.*, Science **351** 587 (2016)
[3] T. Jungwirth *et al.*, Nat. Nanotechn. **11** 231 (2016)
[4] M. Meinert *et al.*, arxiv.org/abs/1706.06983 (2017)

MA 54.4 Fri 8:45 EB 301

Anomalous Hall Effect in Cr_2O_3/Metal Thin Film Systems — •Asser Elsayed, Tobias Kosub, Jürgen Lindner, Jürgen Fassbender, and Denys Makarov — Helmholtz-Zentrum Dresden-Rossendorf e.V., Institute of Ion Beam Physics and Materials Research, Dresden, Germany

Antiferromagnetic thin films have recently shown their promise for applications, such as memory devices [1, 2]. One of these emerging concepts is the AF-MERAM, i.e. antiferromagnetic RAM that uses magnetoelectric materials such as Cr_2O_3.

An important aspect of memory devices is a strong readout signal. In an AF-MERAM the readout is done through a metal layer that is in contact with the boundary magnetization of Cr_2O_3 [3]. While reliable [1], the signal obtained in this way is quite weak. In order to increase the readout signal, we explore different metal layers in the Al_2O_3/Cr_2O_3/Metal stack, e.g. Pt, Ta and Pd, which have differently strong spin Hall and magnetic proximity effects.

[1] T. Kosub et al., Nature Commun. 8, 13985 (2017).
[2] T. Jungwirth et al., Nature Nanotech. 11.3, 231-241 (2016)
[3] T. Kosub et al., Phys. Rev. Lett. 115, 097201 (2015).

MA 54.5 Fri 9:00 EB 301

Temperature dependence of the generation and transport of pure spin currents using the spin Hall effect and spin injection — •Alexander Pfeiffer[1,2], Robert M. Reeve[1], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Mainz, Germany

The spin Hall effect (SHE), observed in nonmagnetic heavy metals with large spin orbit coupling such as Platinum and Tungsten, has received remarkable recent interest as an attractive alternative to electrical spin injection for the generation of spin currents. Such spin currents can be employed to switch magnetic bits efficiently in low power data storage devices [1]. Given surprising results of the temperature dependence of spin current generation and transport in lateral spin valves [2], we study multi-terminal Py-Pt-Cu based lateral spin valve structures. We inject spin currents into the Copper via both the SHE in Platinum and spin injection from Permalloy and compare both conventional non-local signals and those generated via the inverse spin Hall effect (iSHE) in a single device as a function of temperature. We observe a different temperature behaviour in the different cases, which we explain by the different mechanisms occuring in the Platinum and Permalloy and highlighting the governing temperature dependence of the spin injection rather than the spin transport as previously expected. [1] N. Motzko et al., Phys. Rev. B 88, 214405 (2013) [2] A. Pfeiffer et al., Appl. Phys. Lett 107, 082401 (2015)

MA 54.6 Fri 9:15 EB 301

Topological and anomalous Hall and Nernst effect in $Mn_3X\,(X = Ge$ and $Sn)$ — •Ilias Samathrakis[1], Jürgen Weischenberg[2], and Hongbin Zhang[1] — [1]Institute of Materials Science, TU Darmstadt, 64287 Darmstadt, Germany — [2]Department of Physics, RWTH Aachen University, 52074 Aachen, Germany

Antiferromagnets have recently become a hot research topic for spintronic applications. Unlike ferromagnets, they are robust against perturbations due to magnetic fields. Consequently, non-collinear magnets have also attracted some interest, being part of the antiferromagnetic spintronics. An interesting series of non-collinear antiferromagnets that has been extensively studied is $Mn_3X\,(X = Ge$ and $Sn)$. The combination of magnetic frustration and the relatively small energy difference among possible magnetic configurations make them ideal candidates. Till now, a consistent theory for the angular dependence of the anomalous hall conductivity and its physical origin is still missing. In this work, we performed calculations on both the intrinsic and the side-jump contributions, with (anomalous), as well as without (topological) spin-orbit coupling. It is observed that the angular dependence of the anomalous Hall conductivity is unusual. Detailed comparison between Mn_3Ge and Mn_3Sn is shown focusing on the magnitude of their anomalous Hall and anomalous Nernst effects, where significant side jump contribution due to impurities.

MA 54.7 Fri 9:30 EB 301

Growth, structural characterisation and magnetotransport measurements in Mn_3X (X = Ir, Ge) thin-films — •James M Taylor[1], Edouard Lesne[1], Anastasios Markou[2], Pranava K Sivakumar[1], Fasil K Dejene[1], Claudia Felser[2], and Stuart S P Parkin[1] — [1]Max Planck Institute for Microstructure Physics, D-06120 Halle, Germany — [2]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Antiferromagnetic (AFM) materials have undergone a resurgence in interest due to their potential applications in spintronic devices operating without net magnetization. Non-collinear AFMs are particularly promising, with the topological character of their chiral spin texture yielding novel phenomena such as a large anomalous Hall effect and an intrinsic spin Hall effect.

In this work, we report the magnetron sputtering growth of thin-films of the non-collinear AFMs Mn_3Ir and Mn_3Ge. Structural characterisation demonstrates epitaxial (111) and (001) texture in Mn_3Ir and hexagonal Mn_3Ge. Measurements of magnetic properties are shown, including XMCD and exchange bias fields up to H_{Ex} = 306 Oe when coupled to a ferromagnetic (FM) layer.

Finally we present electrical transport measurements, as a function of temperature and applied magnetic field, in lithographically patterned devices. Anomalous Hall effect (modifiable by a layer with strong spin-orbit coupling) is observed at low-temperatures, and spin Hall magnetoresistance investigated in AFM-FM bilayers. Possible origins of these effects, including interfacial contributions, are discussed.

MA 54.8 Fri 9:45 EB 301

Theoretical description of the electric-field induced XMCD at a ferromagnet/non-magnet interface — •Alberto Marmodoro, Sebastian Wimmer, and Hubert Ebert — Dept. Chemie, LMU, München

Bidimensional heterostructures composed of magnetic and non-magnetic materials allow to investigate how spin polarization effects do not cease abruptly at the interface, but extend across it and give rise to a variety of phenomena, that are typically controlled by the details of composition and geometry. Recent experiments [1-2] have furthermore explored how this situation is changed by application of an electric field that drives a steady flux of carriers through the subsystems, and thus go well beyond a ground state regime. We consider in particular X-ray absorption (XAS) and magnetic circular dichroism (XMCD) measurements [3] which can provide element -resolved insight on spin accumulation and its dependence on the direction and magnitude of an external stimulus on top of static, proximity induced influences. This setup is investigated within the spin-polarized relativistic multiple scattering framework (SPRKKR) making use of recent developments [4-5] for the non-equilibrium Green function (NEGF) description of spectroscopy in real materials.

(1) R. Kukreja et al., Phys.Rev.Lett. **115**, 096601, (2015)
(2) G. van der Laan, Physics **8**, 83, (2015)
(3) H. Ebert, Rep.Prog.Phys. **59**, 1665, (1996)
(4) S. Achilles et al., Phys.Rev.B **88**, 125411, (2013)
(5) M. Ogura et al., J.Phys.Soc.Japan **85**, 104715, (2016)

MA 55: Complex Oxides – Bulk Properties, Surfaces and Interfaces (joint session TT/MA/KFM)

Time: Friday 9:30–13:00 Location: H 0110

MA 55.1 Fri 9:30 H 0110

Superconductivity in strontium titanate within the dielectric function method — •Serghei Klimin[1], Jacques Tempere[1], Jozef Devreese[1], Cesare Franchini[2], and Georg Kresse[2] — [1]TQC, Universiteit Antwerpen, Antwerpen, Belgium — [2]University of Vienna, Faculty of Physics and Center for Computational Materials Science, Vienna, Austria

Strontium titanate exhibits unique features which are not encountered in conventional polar crystals at the same conditions. It becomes a superconductor at unusually low carrier densities. $SrTiO_3$ is probably the only substance where superconductivity and optical absorption can be convincingly attributed to the Fröhlich-like electron-phonon interaction and polarons. In the present talk, we report on our theoretical studies of superconductivity in strontium titanate with a comparative discussion of different theoretical interpretations of superconductivity in $SrTiO_3$. It is demonstrated that the dielectric function method used in our works [1] adequately describes the superconducting phase transition using only parameters available from experiments and microscopic calculatuions. We are particularly focused on unusual isotope effect in $SrTiO_3$. It is shown that renormalization of optical-phonon frequencies following from the isotope substitution leads to an increase of the critical temperature within the dielectric function method.

[1] S. N. Klimin, J. Tempere, J. T. Devreese, and D. van der Marel, Phys. Rev. B **89**, 184514 (2014); J. Sup. Nov. Magn. **30**, 757 (2017).

MA 55.2 Fri 9:45 H 0110

Anisotropic Rashba-type spin-orbit coupling of the two-dimensional electron system in (110) $SrTiO_3$-based heterostructures — •Karsten Wolff, Roland Schäfer, Robert Eder, Matthieu le Tacon, and Dirk Fuchs — Karlsruhe Institute of Technology, Institute for Solid State Physics

The two-dimensional electron system in (110) $Al_2O_{3-d}/SrTiO_3$ heterostructures displays anisotropic electronic transport. Structured microbridges allow to probe 4-point resistivity along different crystallographic orientations, i.e. [001] and [1-10]. The conductivity and electron mobility along the [001] direction is largest, while differences in sheet carrier concentration are only minor. The measurements show anisotropic normal magnetotransport for T < 30 K which is correlated to the anisotropic mobility. For temperatures below 5 K transport is dominated by Rashba-type spin orbit interaction (SOI) which displays anisotropic behavior, too. SOI is found largest along the [001] direction.

MA 55.3 Fri 10:00 H 0110

Thermoelectric properties of $(SrXO_3)_1(SrTiO_3)_m(001)$ superlattices, X=V, Mn and Ru — •Manish Verma, Benjamin Geisler, Markus E. Gruner, and Rossitza Pentcheva — Department of Physics and Center for Nanointegration (CENIDE), University of Duisburg-Essen, 47057 Duisburg

The thermoelectric properties of $SrTiO_3$ have been widely studied, primarily concerning the role of homogeneous bulk doping. However, the confinement realized in oxide superlattices may have a favorable effect on the thermoelectric properties. To this end we have investigated the electronic and thermoelectric properties of superlattices containing a monolayer of $SrXO_3$ (X=V, Mn and Ru) sandwiched between m=1,3 spacer layer(s) of $SrTiO_3$ (001) using a combination of density functional theory with an on-site Hubbard term and semi-classical Boltzmann theory. In all cases structural distortions containing octahedral tilts are energetically favored over tetragonal distortions and we explore their influence on the electronic and thermoelectric properties. Comparing the in-plane and out-of-plane transport properties we find no significant dependence on m for the in-plane transport properties. In turn on reduction of the $SrTiO_3$ thickness from m=3 to 1 enhances the dispersion along Γ-Z and thereby improves the out-of-plane thermoelectric properties. Funded by the DFG, CRC/TRR80 project G8.

MA 55.4 Fri 10:15 H 0110

Thermoelectricity close to a metal-insulator transition in ultrathin $LaNiO_3/LaAlO_3(001)$ superlattices — •Benjamin Geisler and Rossitza Pentcheva — Fakultät für Physik, Universität Duisburg-Essen, 47057 Duisburg, Germany

Transition metal oxides are a promising materials class for thermoelectric applications due to their chemical and thermal stability and environmental friendliness. Their thermoelectric response can be further improved by nanostructuring and reduced dimensionality. Here we explore the thermoelectric properties of $(LaNiO_3)_1/(LaAlO_3)_1(001)$ superlattices near the confinement-induced metal-insulator transition by combining *ab initio* simulations including on-site Coulomb repulsion and Boltzmann theory. We find that the short-period vertical design strongly enhances the in-plane thermoelectricity owing to the Ni-site disproportionation, which is stabilized considerably by tensile epitaxial strain and octahedral tilting. The sensitivity of the system to epitaxial strain provides an additional parameter to optimize the thermoelectric performance. For a $SrTiO_3(001)$ substrate, we predict room-temperature Seebeck coefficients and power factors that can compete with those of other oxide systems of current interest such as layered cobaltates. Comparison of the ultrathin superlattices with the metallic longer-period $(LaNiO_3)_3/(LaAlO_3)_3(001)$ case establishes the metal-insulator transition as a crucial mechanism to obtain a high thermoelectric response.

Funding by the DFG within TRR 80 (G3 and G8) is acknowledged.

MA 55.5 Fri 10:30 H 0110

Confinement-driven electronic and topological phases in corundum-derived oxide honeycomb superlattices — •Okan Koeksal and Rossitza Pentcheva — Department of Physics and Center for Nanointegration (CENIDE), University of Duisburg-Essen, 47057 Duisburg

On the basis of density functional theory calculations plus the Hubbard U interaction, we investigate electronic, magnetic and possibly topologically non-trivial phases in X_2O_3 honeycomb layers confined in the corundum structure α-Al_2O_3 (0001). Our results predict that the ground states for most of the systems of $X = 3d$ cations are trivial antiferromagnetic Mott insulators. If the symmetry of the two sublattices is imposed, the ferromagnetic phases of Ti, Mn, Co and Ni exhibit a characteristic set of four bands associated with the single occupation of e_g' (Ti) and e_g (Mn, Co, Ni) states. Moreover, the Dirac point can be tuned to the Fermi level by strain and a significant anomalous Hall conductivity arises when spin-orbit coupling (SOC) is switched on. A particularly strong SOC effect is identified for $X =$ Ti at $a_{Al2O3} = 4.81$ Å accompanied by an unusually high orbital moment of -0.88 μ_B nearly quenching the spin moment of 1.01 μ_B. The emergence of this orbital magnetism makes the realization of Haldane's model of spinless fermions possible. The extension of this work to the 4d and 5d series led to the identification of cases of high orbital moment (Os) or candidates for Chern insulators (CI), i.e. $X =$ Tc and Pt with C=-2 and -1, depending on the Coulomb repulsion strength. Support by the DFG within CRC/TRR80, project G3 is gratefully acknowledged.

MA 55.6 Fri 10:45 H 0110

Metal-Insulator Transition in Thin Films and Multilayers of Early Transition Metal Oxides from DFT+DMFT — •Sophie D. Beck and Claude Ederer — Materials Theory, ETH Zürich, Zurich, Switzerland

The wide variety of interesting phenomena and functionalities of complex oxide thin films and heterostructures is generally determined by a number of different factors, such as substrate-induced epitaxial strain, dimensional confinement, interface-related effects, or defects. Here, we systematically study the interplay between these effects in thin films and multilayers composed of materials such as correlated metals, Mott insulators and band insulators, using a combination of density functional theory (DFT) and dynamical mean-field theory (DMFT). In particular, we investigate the evolution of octahedral rotations across interfaces between two materials with different rotation angles and/or tilt systems, and how this affects the range of electronic reconstruction in the interfacial region. We then show that these effecs can give rise to phenomena such as metallic interfaces in multilayers of two Mott insulators $LaVO_3$ and $LaTiO_3$ up to a metal-insulator transition in the correlated metal $CaVO_3$, for which we find that both tensile strain or reduced film thickness can lead to a strong quasiparticle renormalization.

MA 55.7 Fri 11:00 H 0110

Dimensionality-driven metal-insulator transition in spin-oribt coupled $SrIrO_3$ — •Philipp Schütz[1], Domenico Di Sante[1], Lenart Dudy[1], Judith Gabel[1], Martin Stübinger[1], Martin Kamp[1], Yingkai Huang[2], Massimo Capone[3], Marius-Adrian Husanu[4], Vladimir Strocov[4], Giorgio Sangiovanni[1], Michael Sing[1], and Ralph Claessen[1] — [1]Physikalisches Institut and Röntgen Center for Complex Material Systems (RCCM), Universität Würzburg, Germany — [2]Van der Waals - Zeeman Institute, University of Amsterdam, Netherlands — [3]CNR-IOM-Democritos National Simulation Center and International School for Advanced Studies (SISSA), Italy — [4]Swiss Light Source, Paul Scherrer Institut, Switzerland

Upon reduction of the film thickness we observe a metal-insulator transition in epitaxially stabilized, spin-orbit coupled $SrIrO_3$ ultra-thin films. By comparison of the experimental electronic dispersions with density functional theory at various levels of complexity we identify the leading microscopic mechanisms, i.e., a dimensionality-induced re-adjustment of octahedral rotations, magnetism, and electronic correlations. The astonishing resemblance of the band structure in the two-dimensional limit to that of bulk Sr_2IrO_4 opens new avenues to unconventional superconductivity by "clean" electron doping through electric field gating.

15 min. break.

MA 55.8 Fri 11:30 H 0110

Intrinsic defects effects to the electronic structure of Sr_2IrO_4 probed by scanning tunneling microscopy — •Zhixiang Sun[1], Jose M. Guevara[1], Ekaterina M. Pärschke[1], Steffen Sykora[1], Kaustuv Manna[1,2], Johannes Schoop[1], Andrey Malyuk[1], Sabine Wurmehl[1,3], Jeroen van den Brink[1], Bernd Büchner[1,3], and Christian Hess[1] — [1]IFW-Dresden, 01069 Dresden — [2]MPI-CPfS, 01187 Dresden — [3]Institute for Solid State Physics, TU Dresden

Due to its similarity to cuprates, there is tremendous interest on the possible superconducting ground-state in doped Sr_2IrO_4 (Ir214). Nevertheless, it has been found that doping of Ir214 is difficult. The mechanism of dopant induced insulator to metal transition (IMT) has not been fully clarified. We have carried out low temperature scanning tunneling microscopy/spectroscopy experiments on Ir214 crystals. Several different types of intrinsic defects have been identified and their effects to the local electronic structure have been probed. We noticed that for the apical oxygen site defects, their effects are spatially very localized (< 2 nm). Also on the spectra taken on top of these defects, in gap states with a charge transfer like behavior are observed. With a local defect model we simulated the spectra, which gives good a match with the results. Our results provide important observations on the effects of individual defects on the local electronic properties. This is crucial for further tailoring the electronic structure of Ir214. Furthermore, they can also facilitate the understanding of the general mechanism of IMT in Mott insulators.

MA 55.9 Fri 11:45 H 0110

Novel insights into the impurity-selective metal-insulator transition of paramagnetic V_2O_3 — •Frank Lechermann[1], Noam Bernstein[2], Igor Mazin[2], and Roser Valenti[3] — [1]I. Institut für Theoretische Physik, Universität Hamburg, Jungiusstr. 9, D-20355 Hamburg, Germany — [2]Code 6393, Naval Research Laboratory, Washington, DC 20375, USA — [3]Institut für Theoretische Physik, Goethe-Universität Frankfurt, Max-von-Laue-Str. 1, 60438 Frankfurt am Main, Germany

The phase diagram of V_2O_3 with temperature and concentration of different dopants (e.g. Cr and Ti), still poses a formidable problem in condensed matter physics. By means of the charge self-consistent combination of density functional theory with dynamical mean-field theory, i.e. the DFT+DMFT approach, we provide new clues to the delicate interplay between electronic and lattice degrees of freedom. The impact of the defect chemistry is highlighted beyond the sole lattice expansion/contraction affect usually associated with impurity doping in this system. Local symmetry breakings are identified as one key feature to understand the tight competition between metal and insulator in vanadium sesquioxide.

MA 55.10 Fri 12:00 H 0110

Growth and characterization of *Pmnb*-Li_2FeSiO_4 single crystals — •Waldemar Hergett[1], Christoph Neef[1], Hubert Wadepohl[2], Hans-Peter Meyer[3], Mahmoud Abdel-Hafiez[4], and Rüdiger Klingeler[1,5] — [1]Kirchhoff Institute of Physics, Heidelberg University, Heidelberg, Germany — [2]Institute of Inorganic Chemistry, Heidelberg University, Heidelberg, Germany — [3]Institute of Earth Sciences, Heidelberg University, Heidelberg, Germany — [4]Institute of Physics, Goethe University, Frankfurt, Germany — [5]Center for Advanced Materials, Heidelberg University, Heidelberg, Germany.

Li_2FeSiO_4 single crystals featuring the high temperature *Pmnb* phase were grown by the high-pressure optical floating zone method. The resulting single crystals have been characterized by means of polarised-light and electron microscopy, EDX, powder and single crystal X-ray diffraction. The impact of the growth parameters and of the applied pressure on the crystal quality was investigated. The single crystal structure of the *Pmnb*-polymorph was solved for the first time. It exhibits layers of corner-sharing FeO_4- and SiO_4-tetrahedra in the crystallographic *ac*-planes which alternate with layers of LiO_4-tetrahedra. Magnetisation and specific heat studies confirm the high quality of the crystals and show a sharp λ-like anomaly associated with the onset of long-range antiferromagnetic order at $T_N = 17$ K.

MA 55.11 Fri 12:15 H 0110

Excitonic dispersion of intermediate-spin state in $LaCoO_3$ revealed by resonant inelastic X-ray scattering — •atsushi hariki[1], ru-pan wang[2], andrii sotnikov[1], federica frati[2], jun okamoto[3], hsiao-yu huang[3], amol singh[3], di-jing huang[3], keisuke tomiyasu[4], chao-hung du[5], frenk m. f de groot[1], and jan Kuneš[2] — [1]Institute for Solid State Physics, TU Wien, Austria — [2]Inorganic Chemistry and Catalysis, Debye Institute for Nanomaterials Science, Utrecht University, Utrecht, The Netherlands — [3]Condensed Matter Physics Group, National Synchrotron Radiatiation Research Center, Taiwan, — [4]Department of Physics, Tohoku University, Sendai, Japan — [5]Department of Physics, Tamkang University, New Taipei City, Taiwan,

We perform Co *L*-edge resonant inelastic X-ray scattering of $LaCoO_3$ at 20 K. We observe a dispersive state with an energy shift from 480 to 290 meV as a function of momentum from $\boldsymbol{q} = (0, 0, 0.26\pi)$ to $\boldsymbol{q} = (0, 0, 0.90\pi)$. This dispersion is attributed to the mobility of the intermediate-spin (IS) state, which is viewed as an exciton. A theoretical calculation considering the excitonic dispersion of the IS state on the background of the low-spin (LS) state supports the interpretation. The present result suggests that the mobility pushes the IS state into play to the thermal spin-state transition of $LaCoO_3$ in addition to the (immobile) high-spin and LS states with lower atomic-multiplet energies, as suggested by recent theoretical studies [1].

[1] A. Sotnikov and J. Kuneš, Sci. Rep. 6, 30510 (2016).

MA 55.12 Fri 12:30 H 0110

Electronic signature of the vacancy ordering in NbO (Nb_3O_3) — Anna K. Efimenko[1], Nils Hollmann[1], Katharina Hoefer[1], Jonas Weinen[1], Daisuke Takegami[1], Klaus K. Wolff[1], Simone G. Altendorf[1], Zhiwei Hu[1], A. Diana Rata[1], Alexander C. Komarek[1], Agustinus Nugroho[2], Yen-Fa Liao[3], Ku-Ding Tsuei[3], H. H. Hsieh[4], H. -J. Lin[3], C. T. Chen[3], Liu Hao Tjeng[1], and •Deepa Kasinathan[1] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, Germany — [2]Insitiut Teknologi Bandung, Bandung, Indonesia — [3]National Synchrotron Radiation Research Center, Hsinchu, Taiwan — [4]Chung Cheng Institute of Technology, Taoyuan, Taiwan

We investigated the electronic structure of the vacancy-ordered 4d-transition metal monoxide NbO (Nb_3O_3) using angle-integrated soft- and hard-x-ray photoelectron spectroscopies as well as ultra-violet angle resolved photoelectron spectroscopy. We found that density-functional-based band structure calculations can describe the spectral features accurately provided that self-interaction effects are taken into account. In the angle-resolved spectra we were able to identify the so-called vacancy band that characterizes the ordering of the vacancies. This together with the band structure results indicates the important role of the very large inter-Nb-4d hybridization for the formation of the ordered vacancies and the high thermal stability of the ordered structure of niobium monoxide.

MA 55.13 Fri 12:45 H 0110

Ultrahigh-resolution Resonant Inelastic X-ray Scattering from rare-earth nickelates: magnetic and dd-excitations — •Katrin Fürsich[1], Yi Lu[1], Davide Betto[2], Georg Christiani[1], Giniyat Khaliullin[1], Maurits W. Haverkort[3], Eva Benckiser[1], Matteo Minola[1], and Bernhard Keimer[1] — [1]Max-Planck-Institut für Festkörperforschung, Stuttgart — [2]European Synchrotron Radiation Facility, Grenoble — [3]Institut für Theoretische Physik, Universität Heidelberg

Rare-earth nickelates ($RNiO_3$) have been subject to intense investigation, mostly because of the rich phase diagram comprising a sharp temperature-driven metal-to-insulator transition, an unusual antiferromagnetic ground state, and the prospect of mimicking the physics of high-T_c superconducting cuprates in orbitally engineered heterostructures. We have studied $RNiO_3$ thin-films and superlattices using ultrahigh-resolution resonant inelastic x-ray scattering (RIXS) at the Ni L_3 edge. Below the magnetic ordering temperature, we observe well-defined collective magnon excitations. Our experimental observation provides for the first time a solid basis for the theoretical description of the magnetism in $RNiO_3$. In addition to magnetic excitations, we investigated the electronic excitations of $RNiO_3$ as a function of temperature and tolerance factor, i.e. rare-earth radius. A sophisticated analysis based on an advanced double-cluster model gives intriguing insight into the microscopic and electronic structure of $RNiO_3$. Our study reveals that RIXS is an excellent technique to quantitatively characterize different ordering phenomena within one material.

MA 56: Spin-Hall effects

Time: Friday 9:30–11:15 Location: H 0112

MA 56.1 Fri 9:30 H 0112

Spin transport due to interfacial spin-orbit coupling — •Juan Borge — University of the Basque Country

The inversion symmetry breaking at the interface between different materials generates strong spin-orbit coupling (SOC). This SOC is responsible of different spin phenomena. It generates spin loss at the interface, spin-to-charge, spin-to-spin and charge-to-charge conversion. We will study these phenomena in different metal/metal and ferromagnet/insulator bilayers generated by this interfacial SOC.

MA 56.2 Fri 9:45 H 0112

Spin-pumping in $La_{0.7}Sr_{0.3}MnO_3$/$LaNiO_3$/Pt heterostructures — •Christoph Hauser[1], Camillo Ballani[1], Christian Eisenschmidt[1], Frank Heyroth[2], and Georg Schmidt[1,2] — [1]Martin-Luther Universität Halle-Witteberg, Institut für Physik, Halle — [2]Interdisziplinäres Zentrum für Materialwissenschaften, Universität Halle, Halle

We have investigated spin pumping and the inverse spin Hall effect in heterostructures based on Lathanum Strontium Manganite (LSMO) and Lanthanum Nickel Oxide (LNO). The layers are deposited by pulsed laser deposition on different substrates. Magnetic and structural characterization is done by X-ray, TEM, SQUID magnetometry and ferromagnetic resonance at 120 K. Spin pumping and inverse spin Hall effect are also measured at T = 120 K below the Curie temperature of the LSMO. For LSMO/LNO additional damping in FMR could be detected, however the ISHE signal is too small to be distinguished from artefacts related to rectification of the RF signal in the LSMO. For LSMO/LNO/Pt trilayers, however, a clear ISHE can be detected, indicating that the spin scattering in the LNO is relatively weak while spin puming from the LSMO through the LNO is quite efficient.

MA 56.3 Fri 10:00 H 0112

Spin-charge conversion in PBTTT π-conjugated polymer — •Mohammad M. Qaid[1], Olga Zadvorna[2], Henning Sirringhaus[2], and Georg Schmidt[1] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle — [2]Cavendish Laboratory, University of Cambridge, J. J. Thomson Avenue, Cambridge CB3 0HE, United Kingdom

Spin pumping can be used to inject a pure spin current from a ferromagnet into a conducting non-magnet. By the inverse spin-Hall effect (ISHE) this spin current can be converted into a charge current, an effect also dubbed spin-charge conversion. We have investigated the ISHE in the π-conjugated polymer poly (2,5-bis (3-hexadecylthiophen-2-yl) thieno [3,2-b] thiophene) PBTTT doped with F4TCNQ. The material is deposited on a ferrimagnetic yttrium iron garnet (YIG) thin film. In ferromagnetic resonance a spin current is injected from the YIG into the PBTTT and the inverse spin-Hall effect can be measured in the organic semiconductor. We have investigated the ISHE for different PBTTT thicknesses and also for samples which were annealed in order to change the doping. In addition we have excluded the Nernst effect which can be induced by thermal gradients caused by the RF excitation.

MA 56.4 Fri 10:15 H 0112

Surface magnetization probed by spin Hall magnetoresistance — •Saül Vélez[1,2], Juan Manuel Gomez-Perez[1], Miren Isasa[1], Edurne Sagasta[1], Amilcar Bedoya-Pinto[1], Lauren McKenzie-Sell[3], Mario Amado[3], Jason W. A. Robinson[3], Josep Fontcuberta[4], Vitaly Golovach[5,6], F. Sebastian Bergeret[5], Luis E. Hueso[1,6], and Felix Casanova[1,6] — [1]CIC NanoGUNE — [2]ETH Zürich — [3]University of Cambridge — [4]ICMAB-CSIC, UAB — [5]CFM-MPC (CSIC-UPV/EHU) and DIPC — [6]IKERBASQUE

Spin Hall magnetoresistance (SMR) in heavy metal(HM)/ferromagnetic insulator(FMI) bilayers is a novel effect governed by the spin transport across the HM/FMI interface. I will show the importance of the interface details in SMR in three different FMI systems: spinel CoFe2O4 (with antiphase boundaries) [1], perovskite LaCoO3 (a ferromagnet induced by epitaxial strain) [2] and garnet Y3Fe5O12 (with surface magnetic frustration due to ion-milling [3] or to ultrathin growth [4]). The SMR measurements allow us to extract the complex surface magnetic properties of those films, which are radically different to their bulk counterparts. Our results point SMR as a new powerful tool for probing the magnetic properties of surfaces.

[1] M. Isasa et al., Phys. Rev. Appl. 6, 034007 (2016). [2] S. Vélez et al., submitted. [3] S. Vélez et al., Phys. Rev. B 94, 174405 (2016). [4] J. M. Gómez-Pérez et al., submitted.

*Currently working at ETH Zürich with Prof. Fiebig and Prof. Gambardella.

MA 56.5 Fri 10:30 H 0112

Spin Hall magnetoresistance in antiferromagnetic NiO — Johanna Fischer[1], Olena Gomomay[2], Richard Schlitz[3], Kathrin Ganzhorn[1], Nynke Vlietstra[1], Matthias Althammer[1], Hans Huebl[1], •Matthias Opel[1], Rudolf Gross[1], Sebastian T.B. Goennenwein[3], and Stephan Geprägs[1] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Institut für Physik, Johannes Gutenberg Universität Mainz, Germany — [3]Institut für Festkörper- und Materialphysik, Technische Universität Dresden, Germany

We investigate the spin Hall magnetoresistance (SMR) effect in thin film bilayer heterostructures of the paramagnetic metal Pt and the antiferromagnetic insulator NiO. While rotating an external magnetic field in the easy plane of NiO, we record the longitudinal and the transverse resistivity of the Pt layer and observe an amplitude modulation consistent with the spin Hall magnetoresistance. In comparison to Pt on collinear ferrimagnets [1], this modulation is phase shifted by 90° and its amplitude strongly increases with the magnitude of the magnetic field [2]. We explain the observed magnetic field-dependence of the spin Hall magnetoresistance in a comprehensive model taking into account magnetic field induced modifications of the domain structure in antiferromagnets [2]. With this generic model we are further able to estimate the strength of the magnetoelastic coupling [2]. — This work is supported by the DFG via SPP 1538.

[1] M. Althammer *et al.*, Phys. Rev. B **87**, 224401 (2013).
[2] J. Fischer *et al.*, submitted to Phys. Rev. B, arXiv:1709.04158.

MA 56.6 Fri 10:45 H 0112

Unidirectional spin Hall magnetoresistance in highly spin polarized Heusler compound Co_2MnSi — •Christian Lidig, Laura Weisshoff, Stanislav Bodnar, Mathias Kläui, and Martin Jourdan — Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany

The unidirectional spin Hall magnetoresistance (USMR) effect was recently experimentally observed [1] and theoretical described [2] in heavy metal/ ferromagnetic metal bilayer systems. This effect can be used to probe the magnetic state at the interface between the ferromagnet and heavy metal and it scales, similar to the giant magnetoresistance effect, with the spin polarization of the ferromagnet [2]. Correspondingly highly spin polarized materials, for example half metallic materials, should yield to larger effects. Previous photoemission experiments proved the half metallicity of Co_2MnSi (CMS) and showed a high spin polarization (93%) for a free surface of CMS [3]. However, it is not clear how the high surface spin polarization effects the spin transport measurements. Here I will present spin hall magnetoresistance measurements on CMS / Pt bilayer structures showing a large unidirectional spin hall magnetoresistance effect, originating from the high spin polarization of CMS. [1] C.O. Avci et al., Nat Phys. **11**, 570 (2015). [2] S.S.-L. Zhang et al., Phys Rev B, **94**,140411 (R) (2016). [3] M. Jourdan et al., Nat. Commun. **5**, 3974 (2014).

MA 56.7 Fri 11:00 H 0112

Thicknesses effect of MnGa and Pt on current-induced switching spin orbit torque (SOT) in CoGa/$L1_0$ MnGa/(CoGa)/Pt structure with perpendicular magnetic anisotropy (PMA) — •Reza Ranjbar[1,2], Kazuya Suzuki[1], and Shigemi Mizukami[1] — [1]WPI-Advanced Institute for Materials Research, Tohoku University, Sendai, Japan — [2]Current affiliation: Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

The use of SOT has attracted much attention as one of the ways to electrically manipulate the magnetization of magnetic thin films by applying an electrical current [1]. Tetragonal Heusler-like MnGa alloy have very low net-magnetic moments, high PMA, low Gilbert damping, and high spin polarization. Recently, we discovered low-temperature method of chemically growing 1–3-nm-thick MnGa films on B2 ordered CoGa [2]. This enabled us to investigate the SOT in MnGa alloy and then we reported current-induced SOT magnetization switching in CoGa/MnGa/Pt and CoGa/MnGa/MgO films [3,4]. Here, we present the results of our study on current-induced SOT switching in perpendicularly magnetized CoGa/MnGa/Pt trilayers with different thicknesses of MnGa and Pt. We found that the SOT switching is primarily due to the spin-Hall effect. The effect of MnGa (Pt) thickness is discussed in terms of the magnetic properties (resistivity).

[1] I. M. Miron *et al.*, Nature **476** (2011) 189. [2] K. Z. Suzuki *et al.*, Jpn. J. Appl. Phys. **55** (2016) 010305(R). [3] R. Ranjbar *et al.*, Jpn. J. Appl. Phys. **55** (2016) 120302(R). [4] M. Takikawa *et al.*, Appl. Phys. Express **10** (2017) 073004.

MA 57: Focus Session: Spinorbitronics – from efficient charge/spin conversion based on spin-orbit coupling to chiral magnetic skyrmions III (joint session MA/TT)

Time: Friday 9:30–12:45 Location: H 1012

Invited Talk MA 57.1 Fri 9:30 H 1012

Manipulation of interface-induced Skyrmions studied with STM — •Kirsten von Bergmann — University of Hamburg, Germany

Isolated magnetic skyrmions are envisioned as the basis for future spintronic devices. They can be stabilized by a favorable interplay of magnetic exchange, Dzyaloshinskii-Moriya interaction (DMI), anisotropy and Zeeman energy. The Fe/Ir(111) interface is known to exhibit strong DMI [1] and serves as an ideal basis to build up materials that host single skyrmions on the nanometer length scale. Such small magnetic objects can be imaged, characterized and manipulated using (spin-resolved) scanning tunneling microscopy (STM) [2].

Building upon the Fe/Ir(111)-interface a fine-tuning of the relevant magnetic energies is performed by adding metallic overlayers, by adsorption of hydrogen, or by a variation of the strain within the magnetic film. Magnetic field dependent STM measurements can be used to obtain the specific material parameters [3]. In addition, spectroscopy using a non-magnetic tip electrode reveales the correlation between the local magnetoresistance and the non-collinearity of the spin texture [4]. Such a read-out of the local magnetic state could be combined with the demonstated reversible switching between skyrmion and ferromagnet by local electric fields [5].

[1] Heinze et al., Nature Phys. 7, 718 (2011). [2] von Bergmann et al., J. Phys.: Condens. Matter 26, 394002 (2014). [3] Romming et al., Phys. Rev. Lett. 114, 177203 (2015). [4] Hanneken et al., Nature Nanotech. 10, 1039 (2015). [5] Hsu et al., Nature Nanotech. 12, 123 (2017).

MA 57.2 Fri 10:00 H 1012

anisotropic DMI and micromagnetics of antiskyrmions — •Lorenzo Camosi[1], Olivier Fruchart[2], Stefania Pizzini[1], Stanislas Rohar[3], and Jan Vogel[1] — [1]Institut Néel , CNRS , Grenoble, France — [2]INAC-SPINTEC, CNRS, CEA, Grenoble, France — [3]LPS , CNRS , Orsay , France

A review of our pioneer works for understanding the Antiskyrmions physics in ultrathin magnetic layers is presented. They are topological chiral solitons that may be stabilized when the circular symmetry of the spin configuration is broken due to the inversion of the chirality between perpendicular directions.

In the first part of the talk we explain the relationship between crystal and Dzyaloshinskii-Moriya interaction (DMI)symmetry. Moreover the particular case of anisotropic dmi in ultrathin epitaxial Au/Co/W(110) is presented.

In the second part we show a combined analytical and numerical micromagnetic study of the equilibrium energy, size and shape of anti-skyrmionic magnetic configurations. Anti-skyrmions and skyrmions are compared in systems with the same strength of magnetic interactions. We show that in the presence of dipolar interaction energy of the anti-skyrmion is strongly reduced and its equilibrium size increased with respect to the skyrmion.

MA 57.3 Fri 10:15 H 1012

Skyrmions like it Hot - Temperature Dependence of the Skyrmion Hall Effect — •Kai Litzius[1,2,3], Pedram Bassirian[1], Jonathan Leliaert[4], Sascha Kromin[1], Jakub Zazvorka[1], Ivan Lemesh[5], Nico Kerber[1,2], Alexandra Churikova[5], Daniel Heinze[1], Niklas Keil[1], Markus Weigand[3], Gisela Schütz[3], Geoffrey S. D. Beach[5], and Mathias Klaeui[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, 55099 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [3]Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany — [4]Department of Solid State Sciences, Ghent University, Krijgslaan 281-S1, B-9000 Ghent, Belgium — [5]Department of Materials Science and Engineering, Massachusetts Institute of Technology, Cambridge, Massachusetts 02139, USA

Magnetic skyrmions are topologically stabilized nanoscale spin structures that show promise for future spintronic devices. It was found very recently that during their dynamics a sizeable skyrmion Hall angle (SkHA) occurs that surprisingly depends on the skyrmion velocity. [1,2] Different theoretical models have been put forward for the creep [2] and viscous flow [1] regime. By X-ray microscopy, we investigate reproducible skyrmion trajectories at varying temperatures. We find that the angle is independent of the temperature when plotted against the skyrmion velocity and identify two different mechanisms that lead to distinctly different spin Hall angles in the creep and the flow regimes. References: [1] K. Litzius et al., Nat. Phys. 13, 170-175 (2017). [2] W. Jiang et al., Nat. Phys. 13, 162-169 (2017).

MA 57.4 Fri 10:30 H 1012

Bi-stable skyrmion states in Pt/Co/Ir multilayer nanodots as a switchable information memory — •Mateusz Zelent[1], Michał Mruczkiewicza[2], Jaroslav Tóbik[2], Konstantin Guslienko[3,4], and Maciej Krawczyk[1] — [1]Faculty of Physics, Adam Mickiewicz University in Poznan, Poznan, Poland — [2]Institute of Electrical Engineering, Slovak Academy of Sciences, Bratislava, Slovakia — [3]Depto. Fisica de Materiales, Universidad del País Vasco, UPV/EHU, San Sebastian, Spain — [4]IKERBASQUE, the Basque Foundation for Science, Bilbao, Spain

The magnetic skyrmion stability was studied numerically in circular Pt/Co/Ir multilayer stacks with perpendicular magnetic anisotropy and interface Dzyaloshinskii-Moriya interaction (DMI). We have found bi-stable system which can be found in one of the two distinct skyrmion states differing in the skyrmion radius. We demonstrated that two skyrmions can be stabilized due to the different mechanism, primary DMI or primary magnetostatic interaction, leading to small and large size skyrmions, respectively. We developed a technique to compute the total energy of magnetic configurations as a function of the skyrmion diameter, which allows us to estimate the potential barrier between stable states and to explain the influence of dipolar energy contribution on bi-stable skyrmion formation in multilayer dot systems and skyrmion formation in general. Our result can open a new route to develop an efficient skyrmion based memory, with information bit coded as a skyrmion's size. Funded from the EU Horizon 2020, G.A. No. 644348.

MA 57.5 Fri 10:45 H 1012

Skyrmion lifetimes in exchange frustrated ultrathin films — •Stephan von Malottki[1], Pavel Bessarab[2], Anna Delin[3], and Stefan Heinze[1] — [1]Institute of Theoretical Physics and Astrophysics, University of Kiel — [2]School of Engineering and Natural Sciences - Science Institute, University of Iceland — [3]Department of Applied Physics, School of Engineering Sciences, KTH, Kista

The thermal stability of magnetic skyrmions is a key issue for potential applications in spintronic devices. An Arrhenius law can be used to describe the skyrmion lifetime as a function of temperature, which requires knowledge of the energy barrier and the pre-exponential factor. While the energy barrier has already been adressed by several studies [1], the pre-exponential factor for the skyrmion collapse remains unexplored [2,3].

Here, we adress the dependence of the pre-exponential factor on the external magnetic field and demonstrate that it changes qualitatively when exchange frustration is taken into account. We focus on the model system Pd/Fe/Ir(111) [4], described by an atomistic spin model based on parameters from density functional theory [1]. In our approach, the minimum energy paths and thereby the energy barriers are calculated by the geodesic nudged elastic band method, while the pre-exponential factors are determined by harmonic transition state theory [3].

[1] von Malottki *et al.*, Sci. Rep. **7**, 12299 (2017)
[2] J. Wild *et al.*, Sci. Adv. **3.9**, e1701704 (2017)
[3] P. F. Bessarab *et al.*, arXiv:1706.07173v2 (2017)
[4] N. Romming *et al.*, Phys. Rev. Lett. **114**, 177203 (2015)

30 minutes break

Invited Talk MA 57.6 Fri 11:30 H 1012

Magnonics in skyrmion-hosting chiral magnetic materials — •Markus Garst — Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany

Chiral magnets with a Dzyaloshinskii-Moriya interaction possess spatially modulated phases of the ferromagnetic order parameter like helices and skyrmion lattices. We give an overview of the properties of spinwave excitations in such materials [1]. In the presence of a magnetic field, the magnons are characterized by an inherent non-reciprocity, i.e., their dispersion lack reflection symmetry. We discuss the evolution of non-reciprocity as a function of magnetic field, which has been determined by inelastic neutron scattering on MnSi [2,3]. Moreover, Bragg reflection off the periodicity of the magnetic textures naturally result in magnon band structures. This band structure is topologically non-trivial for the skyrmion lattice due its emergent electrodynamics, which is reflected in non-trivial Chern numbers implying the presence of robust magnon edge states [1]. In addition, we discuss the ferromagnetic resonances of the various phases [4] and their non-reciprocity, which has been experimentally probed by spin-wave spectroscopy and Brillouin light scattering.

[1] M. Garst, J. Waizner, and D. Grundler, J. Phys. D: Appl. Phys. 50, 293002 (2017) [2] M. Kugler, et al. Phys. Rev. Lett. 115, 097203 (2015) [3] T. Weber et al. arXiv:1708.02098 [4] T. Schwarze et al. Nat. Mat. 14, 478 (2015)

MA 57.7 Fri 12:00 H 1012

Field-free deterministic ultrafast creation of magnetic skyrmions by spin–orbit torques — Felix Büttner[1], Ivan Lemesh[1], Michael Schneider[2], •Bastian Pfau[2], Christian M. Günther[2,3], Piet Hessing[2], Jan Geilhufe[2], Lucas Caretta[1], Dieter Engel[2], Benjamin Krüger[4], Jens Viefhaus[5], Stefan Eisebitt[2], and Geoffrey S. D. Beach[1] — [1]Massachusetts Institute of Technology, Cambridge, USA. — [2]Max-Born-Institut, Berlin, Germany. — [3]TU Berlin, Berlin, Germany. — [4]Institut für Lasertechnologien in der Medizin und Messtechnik an der Universität Ulm, Ulm, Germany. — [5]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany.

Magnetic skyrmions are a very promising option to realize current-driven magnetic shift registers. Generation, transport and annihilation of skyrmions are fundamental operations in this context. We study the generation and intrinsic dynamics of bubble skyrmions via static and time-resolved X-ray holography, combining sub-30 nm spatial resolution with sub-100 ps temporal resolution. It is demonstrated that single skyrmions can be generated deterministically on subnanosecond timescales in magnetic racetracks using spin–orbit torque pulses. Externally applied in-plane magnetic fields are not required in the process. Furthermore, results on the GHz dynamical behavior of bubble skyrmions are presented, where precision observation of the skyrmion trajectory is indicative of the presence of an inertial mass, connected to the skyrmion topology.

MA 57.8 Fri 12:15 H 1012

Speed limits for Skyrmions — •Jan Müller[1], Ben McKeever[2,3], and Karin Everschor-Sitte[3] — [1]Institut für Theoretische Physik, Universität zu Köln, 50937 Köln, Deutschland — [2]Graduate School Materials Science in Mainz, 55128 Mainz, Germany — [3]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55128 Mainz, Deutschland

Magnetic skyrmions are particle-like textures in the magnetization, characterized by a topological winding number. Nanometer-scale skyrmions have been observed at room temperature in magnetic multilayer structures. The combination of small size, topological quantization, and their efficient electric manipulation makes them interesting candidates for information carriers in high-performance memory devices which rely on mobile bits. Skyrmion racetrack memory devices have been suggested where skyrmions move in a one-dimensional nanostrip. The information in the racetracks is encoded either in the distance between skyrmions or in additional attributes of these, e.g. shifts from the center of the track or different winding numbers. In order to drive skyrmions along the racetrack, it is often suggested to apply spin-polarized currents. Besides moving the skyrmions, the applied currents, however, also deform them, which is usually assumed a negligible effect. We study these deformations and show that they trigger an instability which ultimately sets a speed limit in the racetracks.

MA 57.9 Fri 12:30 H 1012

Skyrmion-Antiskyrmion racetrack memory in rank-1 DMI materials — M. Hoffmann[1], B. Zimmermann[1], G. P. Müller[1,2], N. S. Kiselev[1], C. Melcher[3], and •S. Blügel[1] — [1]Peter Grünberg Institut & Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, Jülich, Germany — [2]Science Institute of the University of Iceland, VR-III, Reykjavík, Iceland — [3]Department of Mathematics I & JARA FIT, RWTH Aachen University, Aachen, Germany

Recently, we extended the scope of skyrmions and antiskyrmions and introduced a classification scheme of chiral magnets [1]. Typically investigated Bloch-type skyrmions in B20 alloys and Néel-type skyrmions at (111) oriented interfaces belong to isotropic rank-three DM bulk and rank-two DM film magnets with a DM interaction described by a single spiralization constant. Within this class, antiskyrmions are stable only for bulk crystals with certain point group symmetries. New are the anisotropic rank-two DMI film magnets where skyrmions and antiskyrmions can coexist while the determinant of the spiralization tensor determines which of them has lower energy. Finally, zero determinant indicates a rank-one DMI material in which skyrmions and antiskyrmions have the same energy. Here, we discuss our new classification scheme and discuss the potential of rank-one solids for the design of a racetrack memory based on the coexistence of skyrmions and antiskyrmions where the information is encoded in the object type instead of the presence or absence of a skyrmion [2].

[1] M. Hoffmann et al., Nat. Commun. 8, 308 (2017)
[2] M. Hoffmann et al., to be submitted

MA 58: Surface magnetism II

Time: Friday 9:30–11:00 Location: EB 202

MA 58.1 Fri 9:30 EB 202

Magnetic structure of MnO_2 and FeO_2 chains on Ir(100) investigated by spin-polarized STM — •Martin Schmitt, Matthias Vogt, Ryan Cotsakis, Jeannette Kemmer, and Matthias Bode — Physikalisches Institut, Experimentelle Physik II, Universität Würzburg, Am Hubland, D-97074 Würzburg, Germany

Low-dimensional systems are known to behave different from bulk properties. In particular, for monatomic $3d$ transition metal chains unconventional magnetic ground states have been theoretically predicted [1]. Recently, a new self-organized growth method of transition metal oxide (TMO) chains with a structural (3×1) unit cell on Ir(100) has been reported [2]. DFT calculations predict a rather strong antiferromagnetic (AFM) coupling along MnO_2 and FeO_2 chains, but only a weak AFM interaction across the chains. We performed low-temperature spin-polarized scanning tunneling microscopy (SP-STM) to unravel the spin structure of various TMO chains on Ir(100) at 5 K. Our results confirm an AFM coupling for MnO_2 and FeO_2 along the stripes. Surprisingly, we also find pronounced magnetic order in between adjacent chains. Whereas a ferromagnetic (FM) inter-stripe coupling leading to a (3×2) magnetic unit cell is found for FeO_2, MnO_2 chains show a complicated non-collinear ground state with a (9×2) magnetic unit cell. Potential ordering mechanisms which may lead to this spin structure will be discussed.

[1] M. Tanveer *et al.*, Phys. Rev. B **94**, 094403 (2016); further references therein.
[2] P. Ferstl *et al.*, Phys. Rev. Lett. **117**, 046101 (2016).

MA 58.2 Fri 9:45 EB 202

Spin-Resolved Spectroscopy of the Yu-Shiba-Rusinov States of Individual Atoms — Lasse Cornils[1], Anand Kamlapure[1], Lihui Zhou[1,3], Saurabh Pradhan[2], Alexander A. Khajetoorians[1,4], Jonas Fransson[2], •Jens Wiebe[1], and Roland Wiesendanger[1] — [1]Department of Physics, Hamburg University, D-20355 Hamburg, Germany — [2]Department of Physics and Astronomy, Uppsala University, Uppsala SE-751 21, Sweden — [3]Max Planck Institute for Solid State Research, D-70569 Stuttgart, Germany — [4]Institute for Molecules and Materials (IMM), Radboud University, Nijmegen 6525 AJ, Netherlands

A magnetic atom in a superconducting host induces so-called Yu-Shiba-Rusinov (YSR) bound states inside the superconducting energy gap. By combining spin-resolved scanning tunneling spectroscopy with simulations we demonstrate that the pair of peaks associated with the YSR states of an individual Fe atom coupled to an oxygen-reconstructed Ta surface gets spin polarized in an external magnetic field [1]. As theoretically predicted, the electron and hole parts of the YSR states have opposite signs of spin polarizations which keep their spin character when crossing the Fermi level through the quantum phase transition. The simulation of a YSR state right at the Fermi level reveals zero spin polarization which can be used to distinguish such states from Majorana zero modes in chains of YSR atoms.

[1] L. Cornils, A. Kamlapure, L. Zhou, S. Pradhan, A. A. Khajetoorians, J. Fransson, J. Wiebe, and R. Wiesendanger, Phys. Rev. Lett. **119**, 197002 (2017).

MA 58.3 Fri 10:00 EB 202

Tuning a Yu-Shiba-Rusinov state across a quantum phase transition — •Laëtitia Farinacci, Gelavizh Ahmadi, Gaël Reecht, Michael Ruby, Benjamin W. Heinrich, and Katharina J. Franke — Freie Universität Berlin, Arnimallee 14, 14195 Berlin

Magnetic impurities on superconductors induce an exchange scattering potential that locally perturbs the pairing of the superconductor's electrons. This leads to the presence of Yu-Shiba-Rusinov (YSR) states within the gap of the superconductors whose energy depends on the coupling strength between the impurity and Cooper pairs. In particular, upon increase of this coupling strength, the ground state of the system undergoes a quantum phase transition from a free to a screened spin state.

Here, we investigate YSR states induced by Fe-porphin molecules on Pb(111). Upon tip approach we are able to continuously tune their energy across the Fermi energy and thus study, on the single impurity level, such a quantum phase transition.

MA 58.4 Fri 10:15 EB 202

Valence and magnetism of samarium single atoms and clusters on noble metal surfaces — •Alessandro Barla[1], César Moreno[2], Miguel Angel Valbuena[2], Sanjoy K. Mahatha[1], Luca Persichetti[3], Corneliu Nistor[3], Sylvie Godey[2], David Coffey[5], José Ignacio Arnaudas[5], Pierluigi Gargiani[4], Pietro Gambardella[3], Aitor Mugarza[2,6], and Carlo Carbone[1] — [1]Istituto di Struttura della Materia, CNR, Trieste, Italy — [2]Catalan Institute of Nanoscience and Nanotechnology (ICN2), Cerdanyola del Vallès, Spain — [3]Department of Materials, ETH Zürich, Zürich, Switzerland — [4]ALBA Synchrotron Light Source, Cerdanyola del Vallès, Spain — [5]Instituto de Nanociencia de Aragón, Universidad de Zaragoza, Zaragoza, Spain — [6]Institució Catalana de Recerca i Estudis Avançats (ICREA), Barcelona, Spain

There is currently strong interest in the magnetic properties of individual rare-earth atoms, after the discovery of magnetic remanence of Ho adatoms adsorbed on the MgO surface [1]. We present our results on the electronic and magnetic properties of samarium individual atoms and small clusters adsorbed on noble metal surfaces [Cu(111), Ag(111) and Ag(100)]. Our combined XMCD and STM investigations show that Sm atoms and small 2D clusters are in a divalent state characterized by van Vleck paramagnetism. A magnetically almost isotropic trivalent component appears as soon as the second Sm layer starts growing. From the third Sm layer the growth becomes three-dimensional and larger clusters exhibit superparamagnetism with a strong out-of-plane magnetic anisotropy. [1] F. Donati et al., Science 352, 318 (2016)

MA 58.5 Fri 10:30 EB 202

Scanning tunneling spectroscopy of 3d transition metal atoms on superconducting Re(0001) — •Lucas Schneider, Manuel Steinbrecher, Levente Rósza, Jens Wiebe, and Roland Wiesendanger — Department of Physics, Hamburg University, 20355 Hamburg, Germany

Yu-Shiba-Rusinov (YSR) bands in chains of magnetic atoms on s-wave superconductors can host Majorana bound states at their ends [1,2]. For the realization of braiding of these states, which is ultimately needed for their usage in quantum computation, the building of controlled nanostructures of chains and an understanding of the coupling of the magnetic atoms to the substrate, are essential ingredients. In this study, different 3d transition metal adatoms were deposited on a superconducting Rhenium substrate which enables atom-by-atom assembly of nanostructures using the tip of a scanning tunneling microscope as a tool to move the atoms on the surface. The YSR states and spin-excitations of the atoms were investigated by inelastic scanning tunneling spectroscopy in comparison to theoretical *ab-initio* calculations revealing that the YSR state formation crucially depends on the species of atom and its adsorption site.

We acknowledge funding by the ERC via the Advanced Grant ASTONISH (No. 338802).

[1] S. Nadj-Perge *et al.*, Science **346**, 6209 (2014). [2] M. Ruby *et al.*, Nano Letters **17**, 4473, (2017).

MA 58.6 Fri 10:45 EB 202

Spin-resolved dispersion relation of a single Co island — •Hirofumi Oka and Tadahiro Komeda — Institute of Multidisciplinary Research for Advanced Materials, Tohoku University, Katahira 2-1-1, Aoba-ku, Sendai 980-8577, Japan

Scanning tunneling microscopy and spectroscopy (STM/STS) are powerful tools to study on the nanometer (nm) scale spatial modulations of the electronic local density of states (LDOS), which are caused by quantum interference between electron waves scattered off nanostructure boundaries. The analysis of modulation patterns gives the dispersion relation of electronic states. When electrons are confined to magnetic nanostructures, spin-dependent quantum interference occurs and spatial modulations of the LDOS become spin-polarized [1]. Here we report on the observation of spin-polarized modulations of the LDOS within a single Co island on Cu(111) using spin-polarized STM/STS (SP-STM/STS). We show that the spin-resolved dispersion relation of surface states of a nm-small Co island can be obtained by analyzing the spin-polarized LDOS modulations.

[1] H. Oka, P.A. Ignatiev, S. Wedekind, G. Rodary, L. Niebergall,

V.S. Stepanyuk, D. Sander, and J. Kirschner, Science 327, 843 (2010).
*Present address (H.O.): Advanced Institute for Marerials Research (AIMR), Tohoku University, Katahira 2-1-1, Aoba-ku, Sendai 980-8577, Japan.