MA 20: Poster I

Time: Tuesday 16:30–19:00 Location: Poster A

MA 20.1 Tue 16:30 Poster A

Efficient excitation of surface-acoustic waves with impedance-matched IDTs — •Kawa Noman, Yanik Kunz, Kevin Künstle, Vitaliy Vasyuchka, and Mathias Weiler — Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau(RPTU),Kaiserslautern,Germany

Microwave filters based on surface acoustic wave (SAW) devices exhibit minimal loss and operate at high frequencies. Here we study the efficient generation and detection of high amplitude SAWs with multichromatic waveforms. This involves the use of custom-designed interdigital transducers (IDTs) that are lithographically fabricated on piezoelectric substrates such as lithium niobate (LiNbO3). We use microwave stub tuners to match the IDT impedance to the external microwave circuit to maximise the power transfer and analyse the SAW devices using a vector network analyzer. Achieving a precise 50-ohm impedance match resulted in reduced insertion loss and voltage standing wave ratio. High-amplitude SAWs can be used for non-linear magnon generation [1].

[1] M. Geilen et. al, arXiv:2201.04033 (2022).

MA 20.2 Tue 16:30 Poster A

Dynamical Renormalization of a Spin Hamiltonian via High-order Nonlinear Magnonics — •Julian Bär[1], Christoph Schönfeld[1], Lennart Feuerer[1], Alfred Leitenstorfer[1], Dominik Juraschek[2], and Davide Bossini[1] — [1]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany — [2]School of Physics and Astronomy, Tel Aviv University, Tel Aviv 69978, Israel

A key question of the research field of ultrafast magnetic phenomena addresses the generation and control of magnons on fundamental timescales. Standard approaches involve resonant or non-resonant excitation of low-frequency one-magnon modes. High-frequency pairs of magnons near the edges of the Brillouin zone have also been non-resonantly induced. However, most studies disclosed spin dynamics, which are described by linear spin-wave theory. Our work utilizes a high-field laser source in the multi-THz regime to directly excite zone-edge magnons in Hematite. This pumping scheme induces an unexplored magnetic excited state. Theoretical predictions suggest that this excited state can result in strongly nonlinear magnetic phenomena. By tuning the photon energy of the mid-infrared laser, we investigate the spin dynamics induced both via resonant and non-resonant excitation of the two-magnon mode. Experimental results demonstrate coherent coupling between photo-driven high-energy magnons and zone-center modes. The photoexcitation drives the system to an extreme nonequilibrium state, significantly altering the spectrum of zone-center modes. These findings highlight the potential to manipulate the magnonic dispersion on femtosecond timescales through purely magnetic processes.

MA 20.3 Tue 16:30 Poster A

Impact of metallic magnet stray-field on propagating spin waves — •Matthias Wagner[1], Felix Kohl[1], Andrea del Giacco[2], Maria Cocconcelli[2], Silvia Tacchi[3], Riccardo Bertacco[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Department of Physics, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]Department of Physics, Politecnico di Milano, Italy — [3]Istituto Officina dei Materiali (IOM) del Consiglio Nazionale delle Ricerche (CNR), Sede Secondaria di Perugia, Italy

The properties of magnonic waveguides, such as the static magnetization and the spin-wave dispersion, can be changed using external magnetic fields. For the application of magnonic devices, an energy efficient on-chip realization of a bias field is desirable that can manipulate the spin-wave properties either globally or locally. In our current feasibility study, we utilise the stray field of microstructured ferromagnets as a bias field source, investigating its effect on low damping magnonic waveguides. We employ micro-focused Brillouin light scattering spectroscopy to extract spin-wave properties and their resonance frequencies with high spatial resolution. Our experimental results are supplemented by extensive micromagnetic simulations using Mumax^3. Funding by the European Union within the HORIZON-CL42021-DIGITAL-EMERGING-01 Grant No. 101070536 M&MEMS is acknowledged.

MA 20.4 Tue 16:30 Poster A

Wide-band nonreciprocal transmission of surface acoustic waves — •Stephan Glamsch, Matthias Küss, Andreas Hörner, and Manfred Albrecht — Institute of Physics, University of Augsburg, 86135 Augsburg, Germany

Surface acoustic waves (SAWs) are utilized in everyday devices as rf-filters and sensors. However, SAWs are in general propagating reciprocally, which means that the acoustic wave properties do not change under an inversion of the propagation direction. Resonantly coupled to spin waves (SWs) in a magnetic material, the SAW transmission can instead become nonreciprocal, which holds potential for novel microwave devices, e.g. acoustic diodes. Large nonreciprocal SAW transmission in a limited frequency range close to the punctual intersection of SAW and SW dispersions have been recently demonstrated [1]. Nevertheless, nonreciprocal SAW transmission over a wide frequency band has only been theoretically predicted until now [2]. In our most recent work, we show the first experimental demonstration of a wide-band nonreciprocal SAW transmission. For that, we adjusted the SW dispersion of a CoFeB/Ru/CoFeB synthetic antiferromagnet (SAF) to match the linear dispersion of the SAW over a frequency range of $2.8\,\mathrm{GHz} < f < 7.0\,\mathrm{GHz}$. Therefore, a low loss (< 0.08 dB) mediated by SAW-SW interaction in the forward direction and large attenuation (> 5dB) in the reverse direction has been achieved.

[1] M. Küß et al., ACS Appl. Electron. Mater. 5, 5103 (2023).
[2] R. Verba et al., Phys. Rev. Appl. 12, 054061 (2019).

MA 20.5 Tue 16:30 Poster A

Spin Hall driven spin-wave emission in PMA materials — •Moritz Bechberger[1], David Breitbach[1], Björn Heinz[1], Abbas Koujok[1], Bert Lägel[1], Carsten Dubs[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, 67663 Kaiserslautern, Germany — [2]INNOVENT e.V. Technologieentwicklung, Jena, Germany

Spin currents have been used extensively in the research field of magnon spintronics, as they allow to compensate the damping of magnonic systems and the generation of coherent, nonlinear magnetic auto-oscillations. However, their application as a source for propagating spin waves is very limited, given the self-confining nature of the oscillation. Here, we investigate the spin-wave emission of an auto-oscillator in a yttrium iron garnet film substituted with gallium atoms (Ga:YIG), which causes a perpendicular magnetic anisotropy. When driven to high spin-wave amplitudes for in-plane configuration, this system exhibits a positive nonlinear frequency shift due to the negative effective magnetization. We inject a spin-current into the Ga:YIG film via the spin Hall effect by applying a DC current to an adjacent platium layer and study the dynamics of the auto-oscillation with respect to the nonlinear frequency shift and a potential spin-wave emission. This research is funded by the DFG - Project No. 271741898, TRR 173-268565370 (B01), and the ERC Grant No. 101042439 CoSpiN.

MA 20.6 Tue 16:30 Poster A

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

Our work focuses on the behavior of magnon Bose-Einstein condensates (BEC) in two-dimensional artificial magnetization landscapes on the length scale of the wavelength of condensed magnons. Measurements are performed using Brillouin light scattering spectroscopy as an optical detection method of magnons. In addition, different thermal patterns in the micrometer range are imprinted onto the yttrium-iron garnet film sample through phase-based wavefront modulation. This procedure changes the temperature-dependent saturation magnetization and subsequently the effective magnetic field. Both of these effects influence the magnon spectrum to varying degrees and cause strong frequency shifts in the dispersion relation. The corresponding spatial variation of the condensate frequency, acting as an artificial potential for the BEC, affects its dynamics and propels magnon supercurrents and Bogoliubov waves. Extended two-dimensional structures are used to investigate the manipulation of the properties of magnon supercurrents, such as direction and intensity. This research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation)-TRR 173/2-268565370 Spin+X (Project B04)

MA 20.7 Tue 16:30 Poster A

Magnon-Fluxon Dynamics in Superconductor/Ferromagnet Periodic Structures — •Björn Niedzielski and Jamal Berakdar — Martin-Luther Universität Halle-Wittenberg, Halle, Germany

Over the past decades coupled superconductor/ferromagnet (SC/FM) materials has been in the focus of research. Hybrid structures of this form are of fundamental interest and hold promising prospects for information technology. One idea is to use the stray field interaction between superconducting matter and ferromagnets to manipulate the propagation of spin waves in a magnonic wave guide. In this way a superconducting vortex lattice can act as a building block for a reconfigurable magnonic crystal with unique properties. Despite intensive research on this subject the fascinating nature of the coupled dynamics of SC/FM hybrids is not fully understood yet and only recently the first experimental evidence for magnon-fluxon-interaction has been found by Dobrovolskiy et al. (Nature Physics, 15, 477 (2019)).

Here we are aiming at understanding the magnetization dynamics of a SC/FM bilayer by simulating such a structure under realistic conditions. To this end we solve the coupled time-dependent Ginzburg-Landau equations for superconductivity and the Landau-Lifschitz-Gilbert equation for the magnetization dynamics. In accordance with the experiment we found that the presence of the vortices leads to the formation of a Bloch-like band structure in the magnonic spectrum. The width and position of these bands was observed to be highly susceptible to various system parameters like the FM geometry and structural imperfections in the vortex lattice.

MA 20.8 Tue 16:30 Poster A

Magnon polarons in an easy-plane ferromagnet — •Konrad Scharff — KIT, Karlsruhe, Deutschland

When the dispersions of spin waves and acoustic phonons cross in energy-momentum space, they tend to hybridize in the presence of a magnetoelastic coupling [1] resulting in a magnon polaron. We study the emergence of magnon polarons in the ordered phase of an easy-plane ferromagnet on a hexagonal lattice. On the level of linear spin wave theory we determine the energy spectrum and evaluate the spin structure factor.

[1] Kittel, C. Interaction of spin waves and ultrasonic waves in ferromagnetic crystals. Phys. Rev. 110, 836*841 (1958).

MA 20.9 Tue 16:30 Poster A

Magneto-Optical Investigation of Magnetoacoustic Waves in Yttrium Iron Garnet / Zinc Oxide Heterostructures — •Kevin Künstle[1], Finlay Ryburn[2], Yannik Kunz[1], Vitaliy Vasyuchka[1], Yangzhan Zhang[2], Timmy Reimann[3], Morris Lindner[3], Carsten Dubs[3], John F. Gregg[2], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU Kaiserslautern-Landau, Kaiserslautern, Germany — [2]Clarendon Laboratory, Department of Physics, University of Oxford, Oxford, United Kingdom — [3]INNOVENT E.V. Technologieentwicklung, Jena, Germany

In recent years, the coupling of surface acoustic waves (SAWs) with spin waves (SWs) in ferromagnetic metals has emerged as a viable option for realising applications such as acoustic diodes, due to the inherently non-reciprocal SAW-SW interaction. However, the coupling of SAWs with SWs in ferrimagnetic insulators has been much less explored. We study SAWs excited by interdigital transducers made of Ti/Au deposited on a GGG/YIG thin film bilayer and covered with a piezo- electric ZnO layer. The ferrimagnetic YIG thin film acts as a source of SWs to which the SAWs can couple. We used micro-focused Bril- louin light scattering (BLS) spectroscopy and vector network analyser measurements to identify the SAW characteristics. We extracted the SAW group velocity and reconstructed the non-linear SAW dispersion in the heterostructure. Furthermore, we studied the magnetic field dependent interaction of the SAWs with SWs.

MA 20.10 Tue 16:30 Poster A

Non-reciprocal phonon-magnon interaction in yttrium-iron-garnet/zinc oxide heterostructures — •Yannik Kunz[1], Julian Schüler[1], Kevin Künstle[1], Finlay Ryburn[2], Yangzhan Zhang[2], Katharina Lasinger[1], John Gregg[2], Philipp Pirro[1], and Mathias Weiler[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, RPTU in Kaiserslautern — [2]University of Oxford

Magnon-based devices provide a promising approach for energy-efficient computation due to low intrinsic losses in materials such as yttrium-iron-garnet (YIG). However, the energy-efficient excitation of magnons in magnetic systems is challenging. A potential solution to this issue entails the exploitation of magnetoacoustic interaction for magnon generation. In this approach, surface acoustic waves (SAWs) are generated using transducers that comprise interdigital electrodes in combination with a piezoelectric thin film. The SAW can couple to magnons under conservation of energy and momentum [1]. We studied the phonon-magnon coupling in heterostructures of YIG covered by piezoelectric Zinc Oxide by performing SAW transmission measurements as a function of magnetic field magnitude and orientation. The observed magnetoelastic coupling of phonons and magnons is non-reciprocal and highly dependent on the angle between the propagation direction of the SAW and the applied magnetic field.

[1] M. Küß, M. Albrecht, and M. Weiler, Chiral Magnetoacoustics, Frontiers in Physics 10, 981257 (2022).

MA 20.11 Tue 16:30 Poster A

Spin-wave devices for hardware-based computing systems — •Jannis Bensmann[1], Dmitrii Raskhodchikov[1,2], Kirill O. Nikolaev[3], Robert Schmidt[1], Johannes Kern[1], Shraddha Choudhary[1], Vladislav E. Demidov[3], Steffen Michaelis de Vasconcellos[1], Wolfram H. P. Pernice[1,2,4], Sergej O. Demokritov[3], and Rudolf Bratschitsch[1] — [1]University of Münster, Institute of Physics and Center for Nanotechnology, 48149 Münster, Germany — [2]University of Münster, Center for Soft Nanoscience, 48149 Münster, Germany — [3]University of Münster, Institute of Applied Physics, 48149 Münster, Germany — [4]Heidelberg University, Kirchhoff-Institute for Physics, 48149 Münster, Germany

Recently, the advent of artificial intelligence systems has intensified the ever-increasing demand for computational power and driven the exploration of novel approaches to building computational systems. One possibility is hardware-based spin-wave computing. A spin wave characterizes a perturbation of the local magnetization that travels through a magnetic material. Spin waves are energy-efficient, broadband (up to THz), and can have wavelengths down to the nanometer range. We use the material yttrium iron garnet (YIG), which is known for its particularly low damping properties. To probe spin waves, we perform optical measurements such as Brillouin-light-scattering spectroscopy. For validation, we compare our experimental results with micromagnetic simulations. Utilizing nanofabrication techniques, we develop building blocks for spin-wave computing devices.

MA 20.12 Tue 16:30 Poster A

All-magnonic non-linear frequency conversion processes — •Paul Rondt, Rouven Dreyer, Chirs Körner, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany

In magnonics, the phase state of spin-wave excitations in magnetically ordered materials can be exploited as a carrier of information for spin-based devices. Over the last decade, non-linear processes, such as three and four-magnon scattering, have pushed magnonics to the next level by demonstrating magnonic counterparts of electronic devices. However, the possibility of frequency up-conversion as a basic functionality for all-magnonic circuits was missing. To understand the potential use of higher-order non-linear processes, we investigated microstructured $Ni_{80}Fe_{20}$ elements by using the phase-sensitive SNS-MOKE approach as a function of element size and shape [1]. By employing this technique, we demonstrated the existence of phase-stable non-linear spin waves oscillating at odd half-integer multiples of the driving frequency and applied a phase-locking scheme [2]. Moreover, we found that for low-frequency excitations an all-magnonic frequency comb emerges spanning over six octaves, allowing to link MHz frequencies from CMOS devices to high-frequency spin-wave excitations in magnonic circuits [3].

References [1] R. Dreyer, et al., Phys. Rev. Mat. 5, 064411 (2021). [2] R. Dreyer, et al., Nat. Commun. 13, 4939 (2022). [3] C. Koerner, et al., Science 375, 1165-1169 (2022)

MA 20.13 Tue 16:30 Poster A

Micromagnetic Simulations of Spin Wave Propagation in Patterned YIG Magnonic Filters — •Luisa J. Borngräber, Stephanie Lake, Seth W. Kurfman, and Georg Schmidt — Institut für Physik, Martin Luther Universität Halle-Wittenberg, Halle,

Germany

A primary objective for magnon-based computing is efficient control of spin wave propagation and long-lived magnon excitations. The former can be achieved through the use of magnonic crystals, while the latter requires low-loss materials (e.g. yttrium iron garnet *or* YIG). However, previous studies on YIG-based magnonic crystals required destructive means [1] of fabricating the devices or required the integration of lossy metallic magnets [2]. An alternative means to produce these devices is to lithographically pattern YIG structures on existing YIG thin films.

Here, we present micromagnetic simulations of magnonic crystals containing only YIG. We show that propagating surface modes (i.e. Damon-Eshbach *or* DE) can be critically suppressed upon incidence with periodic YIG steps in selective bands while maintaining high transmission between these bands. Therefore, these structures produce efficient filtering and propagation in devices that can be fabricated by standard lithographic techniques and room-temperature YIG deposition on existing films [3] without introducing additional damage-induced losses.

References: [1] Serga *et al. J. Phys. D: Appl. Phys.* **43** 264002 (2010). [2] Qin *et al., Nat. Comm.* **9**, 5445 (2018). [3] Hauser *et al. Sci. Rep.* **6**, 20827 (2016).

MA 20.14 Tue 16:30 Poster A

Micromagnetic simulation of nanogratings as possible devices for unidirectional spin wave propagation — •Markus Kügle[1,2], Monika Scheufele[1,2], Matthias Althammer[1,2], Hans Huebl[1,2,3], Stephan Geprägs[1], and Rudolf Gross[1,2,3] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Technical University of Munich, TUM School of Natural Sciences, Physics Department, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Devices enabling unidirectional spin wave (SW) propagation have emerged as promising candidates for the next generation of magnonic logic devices. Here, we investigate a possible realization of such a system in ferromagnetic nanogratings positioned on planar thin films, which act as the SW medium. In this approach, the dipolar coupling induced by the grating is seen as the origin of a finite non-reciprocity in the SW propagation [1]. Using micromagnetic simulations, we first focus on the broadband ferromagnetic resonance response, the SW transport as well as the SW dispersion relation of such ferromagnetic nanogratings. This allows us to determine the mutual coupling regimes of the nanowires when varying wire width and spacing. We then analyze possible unidirectional SW propagation effects in bilayers of ferromagnetic nanogratings on planar ferromagnetic thin films and compare the simulations to experimental results of $Co_{25}Fe_{75}$ nanogratings on yttrium iron garnet thin films.

MA 20.15 Tue 16:30 Poster A

Micromagnetic simulations of spin wave propagation in corrugated waveguides — •Ashfaque Thonikkadavan and Riccardo Hertel — Université de Strasbourg and CNRS, Institut de Physique et Chimie des Matériaux de Strasbourg, F-67000 Strasbourg, France

The spin-wave dynamics in ferromagnets with periodic patterning can display properties of magnonic crystals, like the appearance of magnon band structures with forbidden frequency gaps. A wide variety of magnonic crystals have been investigated over the past years, including arrays of spatially separated nanomagnets and magnetic thin films with periodically modulated material parameters. Progress in three-dimensional magnetic nanofabrication has made it possible to study systems with geometric, rather than structural, modulations. Here, we investigate the magnonic properties of a micron-sized Permalloy thin-film element with a sinusoidally undulated surface using finite-element micromagnetic simulations. In this case, the surface curvature varies periodically, with sub-micron periodicity, while the magnetic material properties and the film thickness (10 nm) are constant throughout the sample. The curvature induces a local shape anisotropy sufficiently strong to align the magnetization perpendicular to the corrugation direction at zero field. We study the spin-wave propagation in Damon-Eshbach geometry and its dependence on the periodicity and amplitude of the modulation. We find that the system shows features of a gapless one-dimensional magnonic crystal. In contrast, a band gap develops when an external field is applied along the corrugation direction, i.e., in the case of backward-volume spin waves.

MA 20.16 Tue 16:30 Poster A

Impact of a lateral gradient in the ferromagnet thickness on the ultrafast response of a spintronic THz emitter — •Paul Alexander Marschall[1], Wolfgang Hoppe[1], Oliver Gückstock[2], Tobias Kampfrath[2], and Georg Woltersdorf[1] — [1]Martin Luther University Halle-Wittenberg, Institute of Physics, Halle (Saale), Germany — [2]Freie Universität Berlin, Physics, Berlin, Germany

Illuminating a nanometer thin metallic bilayer consisting of a ferromagnetic (FM) and a non-magnetic layer (NM) with an intense femtosecond laser pulse launches an ultrafast spin current from the FM into the NM and is subsequently converted into a charge current in the NM. This system is established as a so called spintronic terahertz emitter usable either as source for THz radiation [1] or for on-chip ultrafast current pulses [2]. By applying an external magnetic field the polarity of radiation or current can be fully inverted. Introducing a lateral gradient in the FM thickness leads to a significant ultrafast response which is not switchable by an external magnetic field and depends on the FM thickness. In this study the origin of this signal is systematically investigated.

[1] T. Seifert et al. Efficient metallic spintronic emitters of ultrabroadband terahertz radiation. Nature Photon 10, 483-488 (2016)

[2] W. Hoppe et al., On-chip generation of ultrafast current pulses by nanolayered spintornic terahertz emitters. ACS Applied Nano Materials 4 (7), 7454-7460 (2021)

MA 20.17 Tue 16:30 Poster A

Magnetization manipulation with Terahertz electric currents — •Holger Grisk[1], Robin Silber[2], Jakob Walowski[1], and Markus Münzenberg[1] — [1]Institute of Physics, Greifswald, Germany — [2]IT4Innovations & Nanotechnology Centre, Ostrava, Czech Republic

Operating electronic devices in the Terahertz band remains challenging. Nevertheless, it is important to meet the escalating need for greater computational capacity. Spintronic Terahertz Emitters (STEs) represent a recent breakthrough, allowing for sub-picosecond electric current transients generation using femtosecond laser pulses. STEs, typically a nanometer-thick ferromagnetic/nonmagnetic metal bilayer, might offer integration into electric circuits. For instance, probing the magnetic stack's response to electric current pulses, demonstrated with older LT-GaAs Terahertz Emitters, can now be achieved using STEs as both the source and detector. To facilitate experiments, we develop a shadow mask for optical lithography using direct laser writing. This mask comprises two STEs connected by a gold wire. Diagnostic pump-probe experiments involve pumping the first STE to induce a current transient, while the second Terahertz Emitter's magnetization dynamics are probed using the Time-Resolved Magneto-Optic Kerr Effect (TR MOKE).

MA 20.18 Tue 16:30 Poster A

Magnetization manipulation with Terahertz electric currents — •Holger Grisk[1], Robin Silber[2], Jakob Walowski[1], and Markus Münzenberg[1] — [1]Institute of Physics, Greifswald, Germany — [2]IT4Innovations & Nanotechnology Centre, Ostrava, Czech Republic

Operating electronic devices in the Terahertz band remains challenging. Nevertheless, it is important to meet the escalating need for greater computational capacity. Spintronic Terahertz Emitters (STEs) represent a recent breakthrough, allowing for sub-picosecond electric current transients generation using femtosecond laser pulses. STEs, typically a nanometer-thick ferromagnetic/nonmagnetic metal bilayer, might offer integration into electric circuits. For instance, probing the magnetic stack's response to electric current pulses, demonstrated with older LT-GaAs Terahertz Emitters, can now be achieved using STEs as both the source and detector. To facilitate experiments, we develop a shadow mask for optical lithography using direct laser writing. This mask comprises two STEs connected by a gold wire. Diagnostic pump-probe experiments involve pumping the first STE to induce a current transient, while the second Terahertz Emitter's magnetization dynamics are probed using the Time-Resolved Magneto-Optic Kerr Effect (TR MOKE).

MA 20.19 Tue 16:30 Poster A

THz spin and charge currents in a non-centrosymmetric ferromagnet — Junwei Tong[1], Zdenek Kaspar[1], Afnan Alostaz[1,5], Bruno Serrano[1], Xianmin Zhang[2], Genaro Bierhance[1,4], F. Gerhard[3], Johannes Kleinlein[3], Tobias Kiessling[3], Charles Gould[3], Laurens Molenkamp[3], Tom Seifert[1], and •Tobias Kampfrath[1,4] — [1]Freie Universität Berlin, Germany — [2]Northeastern University, China — [3]Physikalisches Institut der Universität Würzburg (EP3), and Institute for Topological Insulators, Am Hubland, Germany — [4]Fritz Haber Institute of the Max Planck Society, Germany — [5]Jülich Research Center, Germany

Investigating spin-to-charge conversion (SCC) on ultrafast time scales is important for understanding its physical mechanisms and the development of terahertz (THz) sources. SCC may arise from, e.g., the inverse spin Hall effect and spin-galvanic effect, whose experimental separation is challenging. Here, we use a femtosecond laser pulse to excite thin films of the ferromagnetic Heusler compound NiMnSb and measure the emitted THz electromagnetic pulse. We observe THz signals and, thus, ultrafast photocurrents that can be ascribed to SCC by contributions with Rashba- and Dresselhaus-like symmetry. Based on a symmetry analysis, we separate both contributions and find that the related photocurrents exhibit different temporal dynamics. Further, by changing the magnetic field, we observe that the Rashba-like current is mainly induced by ordinary Hall effect, whereas the Dresselhaus-like current is independent of the magnetic field strength. We discuss possible microscopic scenarios of the Dresselhaus-like contribution.

MA 20.20 Tue 16:30 Poster A

Magnetic Alloy Spintronic Teraherz Emitters — •David Stein[1], Robert Schneider[2], Mario Fix[1], Jannis Bensmann[2], Steffen Michaelis des Vasconsellos[2], Rudolf Bratschitsch[2], and Manfred Albrecht[1] — [1]Univerity of Augsburg, Germany — [2]University of Münster, Germany

Spintronic THz emitters are a fairly recent development in spintronics and promise advantages compared to existing semiconductor-based emitters. Different bilayer und multilayer thin film systems and alloys are being investigated, in order to determine the influence of different elements on the THz emission and gain understanding of the underlaying processes. One focus of the investigation is the interface between the thin film bilayers and multilayers, which are investigated using atomic resolution STEM and EDS.

MA 20.21 Tue 16:30 Poster A

Narrow band THz Frequency emission from Micropatterned THz emitters — •Nikos Kanistras[1], Quentin Remy[2], Reza Rouzegar[2], Tobias Kampfrath[2], and Georg Schmidt[1] — [1]Institut für Physik, Martin-Luther Universität Halle Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [2]Department of Physics, Freie Universität Berlin, 14195 Berlin, Germany

THz frequency devices have gained significant attention driven by widespread application potential ranging from communication to nondestructive characterization techniques to astrophysics applications. Spintronic THz Emitters (STEs) show great potential to complement conventional semi-conducting materials due to their straightforward and cost-effective fabrication techniques resulting in seamless on-chip integration with modern device technologies[1].

While typical STEs exhibit a very broad emission spectrum[2], in some cases a narrow emission band may be preferred.

In this work we present a micropatterned spintronic THz emitter based on CoFeB/Pt bilayer, which creates a THz burst corresponding to a narrow band emission at the burst's fundamental frequency. The samples were fabricated by DC sputtering and optical lithography. The THz emission measurements were performed with a wide band detection range up to 40 THz. These devices demonstrate a viable and straightforward method to produce controlled emission in a well-defined THz frequency band.

[1] Seifert et al. Nature Photon 10, 483-488 (2016).
[2] Schmidt et al. Phys. Rev. Appl.,19:L041001 (2023).

MA 20.22 Tue 16:30 Poster A

Theory of spin polarization of transverse electron currents in ferromagnets — •Ilja Turek[1], Alberto Marmodoro[2], Sergiy Mankovsky[3], and Hubert Ebert[3] — [1]Institute of Physics of Materials, Czech Acad. Sci., Brno, Czech Rep. — [2]Institute of Physics, Czech Acad. Sci., Prague, Czech Rep. — [3]Ludwig Maximilians University, Munich, Germany

Motivated by recent theoretical [1] and experimental [2] studies, we discuss selected aspects of the spin Hall effect in ferromagnets. We focus on cases with fixed directions of the applied electric field and of the induced electron current, and investigate the spin polarization of the latter as a function of the direction of magnetization of the ferromagnet. Based on a group-theoretical analysis [3] and on computations for a 2D tight-binding model [1] and for bulk ordered and disordered iron-based systems, we examine the range of validity of a simple formula suggested by Amin et al. [1]. We find that this formula does not contain terms odd with respect to time reversal, which are of various importance in the studied systems.

[1] V. P. Amin et al., Phys. Rev. B 99 (2019) 220405. [2] N. Soya et al., Phys. Rev. Lett. 131 (2023) 076702. [3] M. Seemann et al., Phys. Rev. B 92 (2015) 155138.

MA 20.23 Tue 16:30 Poster A

Soft x-ray detection of spin-orbit torque mediated magnetization switching and exchange bias effect in FeSi thin films — Victor Ukleev[1], Chen Luo[1], James Taylor[1,2], Tomohiro Hori[3,4], Yoshinori Tokura[4,5], Naoya Kanazawa[3], and •Florin Radu[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie, Berlin, Germany — [2]Institute of Physics, Martin-Luther-University Halle-Wittenberg, Halle, Germany — [3]Institute of Industrial Science, The University of Tokyo, Tokyo, Japan — [4]Department of Applied Physics, University of Tokyo, Tokyo, Japan — [5]RIKEN Center for Emergent Matter Science (CEMS), Wako, Japan

The emergence of non-trivial magnetotransport in materials without inversion symmetry challenges the current understanding of magnetic phenomena and paves new ways of coupling spin and orbital degrees of freedom [1]. Recently a topological surface state emergent at the surface of chiral insulator FeSi has been demonstrated [2]. In contrast to bulk FeSi, this surface state has a metallic conductivity and ferromagnetic order below ~150 K. Here, we demonstrate a novel experimental technique based on polarization-dependent synchrotron soft x-ray spectroscopy that allows simultaneous detection of the anomalous Hall effect and bulk-sensitive fluorescence x-ray magnetic circular dichroism. The method allows us to detect spin-orbit torque switching of the surface state magnetization. Furthermore, we observe zero-field switching due to interface-induced exchange bias phenomena. [1] Soumyanarayanan, A. et al., Nature 539, 509*517 (2016). [2] Ohtsuka, Y., et al., Sci. Adv. 7, eabj0498 (2021).

MA 20.24 Tue 16:30 Poster A

Probing Hybrid Chiral-Molecule/Metal Interfaces Via Spin Hall Magnetoresistance — •Simon Sochiera[1], Ashish Moharana[1], David Anthofer[1], Fabian Kammerbauer[1], Jens-Georg Becker[2], Alex Hagenow[2], Eva Rentschler[2], and Angela Wittmann[1] — [1]Institute for Physics JGU, Mainz, Germany — [2]Chemistry Department JGU, Mainz, Germany

Chiral molecules have gained significant attention in the spintronics community due to their ability to polarize electron spin angular momentum. Several optical and electrical methods confirmed the chiral-induced spin selectivity effect (CISS; Nat. Rev. Chem. 3, 250 (2019)). Spin Hall magnetoresistance is a powerful tool to probe the spin-transport properties of the hybrid chiral molecule metal interface. Using this technique, we probe the impact of the adsorption of chiral molecules on metal thin films on the spin transport properties and the interfacial effective spin-orbit coupling of the hybrid system. Understanding the effect of molecules in spintronic devices will open up new possibilities for the development of novel hybrid chiral-molecule spintronic devices.

MA 20.25 Tue 16:30 Poster A

Epitaxy of Fe/Rh bilayers with efficient spin pumping — •Jonas Wiemeler[1], Ali Can Aktas[1], Ivan Tarasov[1], András Kovács[2], Rafal Dunin-Borkowski[2], Michael Farle[1], and Anna Semisalova[1] — [1]Faculty of Physics and CENIDE, University of Duisburg-Essen, 47057 Duisburg, Germany — [2]Ernst Ruska-Centre, Forschungszentrum Jülich, 52428 Jülich, Germany

We investigate the growth and epitaxy of Rh on Fe(001)/GaAs(001)-4x6 ultra thin bilayer deposited using molecular beam epitaxy in ultrahigh vacuum (5E-10 mbar). We use in situ low-energy electron diffraction and Auger electron spectroscopy during growth, as well as cross-sectional transmission electron microscopy, X-ray diffraction and x-ray circular magnetic dichroism, and show that the Fe/Rh interface is atomically sharp and Rh is not magnetically polarised. The fcc-Rh layers grow 45° rotated to the bcc-Fe lattice, that is Rh(001)[110]||Fe(001)[100] to minimise the lattice mismatch to ≈6%. Cross-section TEM reveals high crystallinity with minimal misfit dislocation defects of 0.2 defects/nm at the interface with Fe. Rh grows in a layer-like Stranski-Krastanov mode on the Fe substrate [1]. Using conventional broadband ferromagnetic resonance, we find that the Fe/Rh bilayer system shows a high spin pumping efficiency with the spin-mixing conductance $g_{mix}^{\uparrow\downarrow} = (2.5 \pm 0.2) \cdot 10^{19}\,\mathrm{m}^{-2}$ comparable to that of Fe/Rh bilayers [2,3]. Financially supported by DFG Projects: CRC/TRR 270 No. 10405553726 and No. 39240249 (SE 2853/1-1) [1] T. Kachel et al., PRB 46, 12888 (1992), [2] A. Conca et al., PRB 93, 134405 (2016), [3] T. Papaioannou et al., APL 103, 162401 (2013)

MA 20.26 Tue 16:30 Poster A

Spin transport in Fe_4GeTe_2 van der Waals heterostructures — •Masoumeh Davoudiniya and Biplab Sanyal — Department of Physics and Astronomy, Uppsala University, Box 516, 751 20 Uppsala, Sweden

Through first-principles calculations, this study aims to theoretically investigate the spin-dependent electronic transport properties within Fe_4GeTe_2 (F4GT) -based van der Waals heterostructures, a class of 2D itinerant ferromagnets with a Curie temperature approaching room temperature. We will illustrate spin-polarized ballistic transport in configurations involving single- or bi-layer F4GT interfaced with $PtTe_2$ electrodes. The electronic density of states, whether for free-standing or device-configured F4GT, unequivocally confirms its ferromagnetic metallic character. Notably, it reveals a weak interface interaction between F4GT and $PtTe_2$ electrodes, which preserves the magnetic properties of free standing F4GT. In the scenario of a double-layer F4GT with a ferromagnetic configuration situated between $PtTe_2$ electrodes, an anticipated spin polarization of an impressive 97% is observed. Furthermore, the spin transport characteristics of F4GT/GaTe/F4GT vdW heterostructures, positioned between $PtTe_2$ electrodes, have been studied to assess their potential as magnetic tunnel junctions in spintronic devices. The introduction of GaTe as a 2D semiconducting spacer between F4GT layers yields a tunnel magnetoresistance of 487% at low bias. These findings present novel prospects for formulating and enhancing spintronic devices based on FGT and similar heterostructures.

MA 20.27 Tue 16:30 Poster A

Theory of magnon mediated electric current drag from nonlocal spin-Hall magnetoresistance in the ac regime — •Oliver Franke, Duje Akrap, Ulli Gems, David A. Reiss, and Piet W. Brouwer — Dahlem Center for Complex Quantum Systems and Physics Department, Freie Universitaet Berlin, Arnimallee 14, 14195 Berlin, Germany

The spin-Hall effect (SHE) allows the conversion between an electric and spin current in normal metals with spin-orbit coupling. In bilayer systems consisting of a normal metal (N) and a ferromagnetic insulator (F), this gives rise to a small correction to the electrical resistance of a charge current through N due to a spin-transfer torque acting on the magnetization in F, called spin-Hall magnetoresistance (SMR). It has been proposed and measured that the same effects can cause a nonlocal charge current in N|F|N trilayers, whereby the charge current is transmitted through an electrical insulator by magnons. In this poster, we present a theory for this nonlocal SMR for the first time in the ac regime up to terahertz driving frequencies and derive its local and nonlocal electrical conductivity up to second order in the applied electric field, which includes rectification effects and Joule heating. By employing a diffusive transport theory for thermal magnons and heat, our theory also incorporates the spin Seebeck effect (SSE).

MA 20.28 Tue 16:30 Poster A

Studying Moire magnetism with diamond scanning probe — •King Cho Wong — Physics Institute 3

Moiré superlattices of twisted magnetic two-dimensional (2D) materials are interesting platforms for creating peculiar magnetic states. Here, we report emerging novel magnetic textures in twisted double bilayer chromium triiodide (tDB-CrI3). Using single-spin quantum magnetometry, we directly visualized nanoscale magnetic domains and patterns, and measured domain and domain wall size. In twisted bilayer CrI3, we observed the coexistence of antiferromagnetic (AFM) and ferromagnetic (FM) domains with twisted angle dependence. We also observed peculiar magnetic phase in the samples. Our results highlight magnetic moiré superlattices as a platform for exploring nanomagnetism.

MA 20.29 Tue 16:30 Poster A

Helical magnetic order in a polar Weyl semimetal RAlSi — •Ryota Nakano[1], Rinsuke Yamada[1], Sebastian Esser[1], Masaki Gen[2], Akiko Kikkawa[2], Yasujiro Taguchi[2], Maurice Colling[3], Jan Masell[2,3], Masashi Tokunaga[2,4], Hajime Sagayama[5], Hiroyuki Ohsumi[6], Yoshikazu Tanaka[6], Taka-hisa Arima[2,7], Yoshinori Tokura[1,2,8], and Max Hirschberger[1,2] — [1]Dep. of Applied Physics, University of Tokyo, Japan — [2]RIKEN CEMS, Japan — [3]Inst. of Theoretical Solid State Physics, Karlsruhe Institute of Technology, Germany — [4]ISSP, University of Tokyo, Japan — [5]Inst. of Materials Structure Science, KEK, Japan — [6]RIKEN SPring-8, Japan — [7]Dep. of Advanced Materials Science, University of Tokyo, Japan — [8]Tokyo College, University of Tokyo, Japan

Recently, materials exhibiting both Weyl points and non-collinear or non-coplanar spin textures have been intensely studied. RAlSi/RAlGe (R = rare earth ion) is a promising platform, having Weyl nodes due to their non-centrosymmetric crystal structure, and showing versatile magnetic structures by substituting rare earth ions. Our recent study reveals large anisotropic magnetoresistance in RAlSi. In this presentation, we report various types of helimagnetic order in RAlSi by resonant X-ray scattering measurements, including polarization analysis of the scattered X-rays, at Photon Factory and SPring-8 in Japan.

MA 20.30 Tue 16:30 Poster A

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

Advanced nanofabrication techniques and novel 3D magnetization visualization methods have inspired significant research in 3D nanomagnetism, uncovering intriguing nanostructures and physics beyond the realms of 1D and 2D. A fascinating discovery arising from this exploration is that of magnetic hopfions, three-dimensional topological magnetic textures [1,2,3]. In references [4,5] the stabilization of magnetic Hopfions through higher-order exchange interactions in bulk magnets has been proposed. We investigate theoretically the influence of the different model parameters on the Hopfion properties for Hopfions stabilized by such higher-order exchange interactions. We further look for novel Hopfion stabilization mechanisms.

References:

[1] P. Sutcliffe, Phys. Rev. Lett. 118 (2017)
[2] Y. Liu, et al., Phys. Rev. B 98 (2018)
[3] F. Zheng, et al., Nature 623 (2023)
[4] F. N. Rybakov, et al., APL Mat. 210 (2022)
[5] M. Sallermann, et al., Phys. Rev. B 107(2023)

MA 20.31 Tue 16:30 Poster A

Conservation laws and dynamics of 3D topological spin textures — •Maximilian Röhrich[1], Sopheak Sorn[1], Stavros Komineas[2], and Markus Garst[1] — [1]Karlsruhe Institute of Technology, Germany — [2]University of Crete, Greece

With the advent of 3D magnetic imaging techniques, spin textures varying in three spatial dimensions are at the focus of research with magnetic hopfions being a prominent example. In this work, we investigate the dynamics of such textures from the perspective of fundamental conservation laws associated with translational and rotational symmetry. We show that these symmetries imply the conservation of linear, p, and angular momentum, l, which can be expressed, respectively, in terms of the first and second moment of the vorticity, i.e., the 3D generalization of the topological density. Using these results, we derive equations of motion for the rigid translational and rotational motion of the texture that are parametrized by the conserved quantities p and l. Our analytical results are confirmed by numerical simulations.

MA 20.32 Tue 16:30 Poster A

Effects of curvature and torsion on domain wall velocity in antiferromagnetic helix-shaped spin chain exposed to rotating magnetic field — •Yelyzaveta A. Borysenko[1], Kostiantyn V. Yershov[2], Denis D. Sheka[3], and Jeroen van den Brink[2] — [1]Department of Physics, University of Konstanz, DE-78457 Konstanz, Germany — [2]Institute for Theoretical Solid State Physics, IFW Dresden, 01069 Dresden, Germany — [3]Taras Shevchenko National University of Kyiv, 01601 Kyiv, Ukraine

Antiferromagnetically ordered (AFM) spin chains arranged along space curves possess geometry-driven magnetic interactions, described by chain curvature and torsion. These interactions by symmetry resemble anisotropic and Dzyaloshinskii-Moriya contributions, originate from exchange, dipolar interaction and intrinsic anisotropy in samples of curved shape [1, 2] and determine the ground state and spin dynamics of such systems [2, 3]. Here, we investigate helix-shaped AFM spin chains (constant curvature and torsion) and describe domain wall dynamics in such system being exposed to rotating magnetic field. Domain wall propagates with velocity, proportional to magnetic field frequency. The relation between the external field and geometrical parameters of the spin chain determines two motion modes: oscillating one and rigid motion with a constant velocity. Curvature and torsion strongly affect stability conditions of the rigid motion mode and domain wall velocity. [1] O. V. Pylypovskyi et al., App. Phys. Lett., 118, 182405 (2021); [2] O. V. Pylypovskyi et al., Nano Lett., 20, 8157-8162 (2020); [3] D. Makarov et al., Adv. Mat., 34, 2101758 (2022)

MA 20.33 Tue 16:30 Poster A

Friedel oscillations induced by three-dimensional topological spin-textures — •Moritz Winterott[1,2] and Samir Lounis[1,2] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich & JARA, D-52425 Jülich, Germany — [2]Faculty of Physics, University of Duisburg-Essen and CENIDE, 47053 Duisburg, Germany

Far-reaching progress was made in the field of three-dimensional spin-textures, especially their potential application in upcomming information storage devices is moving efficient identification and interaction between them further into the focus. We examine these exciting questions from a new perspective, inspired by new findings for the two-dimensional skyrmion [1], we find that three-dimensional spin-textures also carry an electric charge that causes Friedel oscillations. These ripples in the charge density trigger exciting questions, for instance all-electrical interaction and identification of these three-dimensional spin-textures. The non-collinearity of a spin-texture induces a redistribution of the charge density with respect to the collinear ferromagnetic background, which we address by employing a tight-binding model, together with multiple scattering theory. We investigate the impact of spin-orbit coupling, exchange splitting, hopping and position of the d-state with respect to the Fermi energy for different three-dimensional spin-textures of different sizes.
– Project funded by DFG (SPP 2137: LO 1659/8-1).
–[1] M. Bouhassoune & S. Lounis, *Nanomaterials* **11**, 194 (2021).

MA 20.34 Tue 16:30 Poster A

Simulation and experimental studies on synthetic antiferromagnets irradiated by focussed He+ ion beam irradiation — •Fabian Samad[1,2], Gregor Hlawacek[2], Toni Hache[2,3], Helmut Schultheiss[2], Attila Kákay[2], and Olav Hellwig[1,2] — [1]University of Technology Chemnitz, Chemnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [3]Max Planck Institute for Solid State Research, Stuttgart, Germany

We present simulation and experimental studies on a synthetic antiferromagnet (SAF) with perpendicular magnetic anisotropy (PMA) [1]. The system is locally manipulated with focused He+ ion beam irradiation on the nano- and micro-scale, inducing the creation of field reconfigurable magnetic textures in the SAF [2]. In a second step we investigate a hybrid system consisting of the SAF and an additional soft magnetic layer on top, with the SAF magnetic textures acting on the soft layer via their stray field. The resulting magnetic structures in the soft layer were probed via magnetic force microscopy (MFM). Our studies demonstrate the possibility to create reconfigurable in-plane oriented regions in the soft layer, which may be utilised, for example, for guiding spin waves in the Damon-Eshbach mode [3,4].

References: [1] Hellwig et al., JMMM 319, 13 (2007) [2] Samad et al., APL 119, 022409 (2021) [3] Qin et al., Nano Letters 22, 5294 (2022) [4] Szulc et al., ACS Nano 16, 14168 (2022)

MA 20.35 Tue 16:30 Poster A

Modeling the training effect in exchange-biased bilayers for large numbers of magnetization reversal cycles — Johannes Fiedler[1], Martin Wortmann[2], Tomasz Blachowicz[3], and •Andrea Ehrmann[1] — [1]Bielefeld University of Applied Sciences and Arts, Faculty of Engineering and Mathematics, Bielefeld, Germany — [2]Bielefeld University, Faculty of Physics, Bielefeld, Germany — [3]Silesian University of Technology, Institute of Physics - Center for Science and Education, Gliwice, Poland

The exchange bias (EB) is a unidirectional anisotropy which occurs, e.g., upon field-cooling ferromagnet/antiferromagnet systems. In many material systems, the EB field is reduced from one hysteresis loop to the next measurement. This so-called training effect (TE) has been investigated in experiments and by means of theoretical efforts by many research groups. The reduction of the EB field as a result of subsequent magnetization reversal processes is often fitted by a power law, usually with the exception of n=1, or with an equation based on the discretized Landau-Khalatnikov (LK) equation, as firstly suggested by Binek. Few other models, usually with more fitting parameters, have been proposed yet. Here we show that for large numbers of subsequent magnetization reversal processes in Co/CoO thin film samples, a modified power law or a logarithmic fit can model the training effect significantly better than the above mentioned, commonly used models.

MA 20.36 Tue 16:30 Poster A

Collective out-of-plane magnetization reversal in tilted stripe domain systems via a single point of irreversibility — •Peter Heinig[1,2], Ruslan Salikhov[1], Fabian Samad[1,2], Lorenzo Fallarino[1,3], Gauravkumar Patel[1], Attila Kákay[1], Nikolai S. Kiselev[4], and Olav Hellwig[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf — [2]Chemnitz University of Technology — [3]CIC energiGUNE — [4]Forschungszentrum Jülich

Periodic magnetic stripe domain patterns are a prominent feature of perpendicular anisotropy thin film systems. Here, we focus on the behavior of $[\mathrm{Co}(3.0\ \mathrm{nm})/\mathrm{Pt}(0.6\ \mathrm{nm})]_X$ multilayers within the transitional regime from preferred in-plane (IP), $X = 6$, to out-of-plane (OOP), $X = 22$, magnetization orientation, particularly, we examine a sample with $X = 11$ repetitions, which exhibits a remanent state characterized by a significant presence of both OOP and IP magnetization components, here referred to as the "tilted" stripe domain state*. We investigate this specific sample with vibrating sample magnetometry, magnetic force microscopy and micromagnetic simulations, and find an unusual OOP field reversal behavior via a remanent parallel stripe domain state and a single point of irreversibility. Finally, we show that this characteristic reversal behavior is a rather general feature of transitional IP to OOP systems by comparing the Co/Pt multilayers with c-axis single Co thin films and Fe/Gd multilayers.
*[L. Fallarino et al., Phys. Rev. B 99, 024431 (2019)]

MA 20.37 Tue 16:30 Poster A

Integration of magnetic garnet thin films on a piezoelectric substrate — •Christian Holzmann, Stephan Glamsch, David Stein, Matthias Küss, and Manfred Albrecht — Institute of Physics, University of Augsburg, Universitätsstraße 1, 86159 Augsburg, Germany

On one hand, rare earth iron garnets are the go-to material to study magnons due to their insulating nature and ultra-low Gilbert damping. On the other hand, surface acoustic waves (SAWs) are broadly used in modern devices, e.g. in RF filters. Therefore, exploiting the coupling of SAWs and magnons in garnets offers the potential to design highly efficient magneto-acoustic devices [1].
However, studies involving garnet thin films are mostly focused on epitaxially grown films, while the implementation on non-matching substrates is challenging [2]. In this regard, we show the growth of about 40 nm thick crystalline yttrium (YIG) as well as gadolinium iron garnet (GdIG) films on the often used piezoelectric substrate $LiNbO_3$. By combining film growth via pulsed laser deposition and a post-deposition annealing step, garnet recrystallization in a polycrystalline phase is achieved. Notably, the YIG film shows an in-plane uniaxial magnetic anisotropy due to a non-isometric strain induced by the substrate, while the GdIG film possesses a magnetic compensation point close to room temperature.
[1] Küß et al., ACS Applied Electronic Materials, 5103 (2023).
[2] Holzmann et al., Encyclopedia of Materials: Electronics, 777 (2023).

MA 20.38 Tue 16:30 Poster A

The importance of adhesion layers for the growth of sputter deposited Co/Pt multilayer systems — •Rico Ehrler[1], Tino Uhlig[1], Felix Engelhardt[1], Fabian Samad[1], Peter Heinig[1,2], and Olav Hellwig[1,2,3] — [1]Chemnitz University of Technology, D-09107 Chemnitz, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, D-01328 Dresden, Germany — [3]Research Center MAIN, D-09126 Chemnitz, Germany

Historically, many studies explored properties of sputter-deposited Co/Pt multilayer (ML) with diverse seed layers and substrates. To improve adhesion, later studies added a thin adhesion layer between oxide substrates and metal seeds, significantly affecting the ML system's structure and magnetics as well.

In our investigation, we employed x-ray reflectivity (XRR), x-ray diffraction (XRD), and atomic force microscopy (AFM) to examine the role of Ta adhesion layers on the structure of a Co/Pt ML system grown on thermally oxidized Si for various sputter deposition pressures. Additionally, we reevaluated the impact of seed layer thickness when using this adhesion layer. Magnetic properties were characterized using SQUID-VSM hysteresis loops and magnetic force microscopy (MFM) images. We found that pressure-dependent structural changes were less pronounced with the Ta adhesion layer, enhancing saturation magnetization and anisotropy, particularly at higher pressures. In contrast, Pt seed layer thickness variations produced minor changes in the ML system's magnetic behavior, differing from older studies without an adhesion layer.

MA 20.39 Tue 16:30 Poster A

Ultrathin Fe and Fe3O4 all-oxide heterostructures: Insights from XPS and MOKE — •Andreas Fuhrberg, Pia Maria Düring, Seema Seema, and Martina Müller — FB Physik - Universität Konstanz, 78464 Konstanz, Deutschland

The interface between two different oxide materials can exhibit emerging properties which may be used in novel oxide electronic devices. In particular, interfaces of 3d transition metal oxides show interesting properties like e.g. confined conductivity, magnetism or ferroelectricity. This work focuses on the interface of the 3d ferromagnetic metal Fe and its oxide Fe3O4 with SrTiO3 (STO). Ultrathin films of Fe with varying thicknesses are deposited on STO (001) substrates by molecular beam epitaxy (MBE) at different temperatures. Using lab- and synchrotron-based x-ray photoelectron spectroscopy (XPS), the chemical properties of the interface with STO are explored and a strongly T-dependent interfacial redox reaction is found.

In-operando hard x-ray photoelectron spectroscopy on MBE-grown Fe3O4 thin films on STO:Nb reveals voltage-dependent changes of the core levels and non-ohmic resistance characteristics.

The magnetic properties of Fe3O4/STO:Nb films with varying oxide thickness are studied using magneto-optic Kerr microscopy (MOKE). Influences originating from the diamagnetic substrate and a shift of the magnetic axes caused by anti-phase boundaries are observed.

MA 20.40 Tue 16:30 Poster A

Growth of Perpendicular Magnetic Anisotropy in Gallium-substituted Yttrium Iron Garnet Thin Films — •Kilian Lenz[1], Olga Gladii[1], Javier Pablo-Navarro[1], Antje Oelschlägel[1], René Heller[1], Jürgen Lindner[1], Oleksii Surzhenko[2], and Carsten Dubs[2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, Dresden — [2]INNOVENT e.V. Technologieentwicklung, Prüssingstrasse 27B, 07745 Jena

The substitution of Fe lattice sites of yttrium iron garnet (YIG) liquid-phase-epitaxy-grown films with non-magnetic Ga ions creates a significant perpendicular magnetic anisotropy (PMA). Magnetometry and broadband ferromagnetic resonance were performed to test the magnetic characteristics of these Ga:YIG thin films. The Ga content was varied between 1.1–1.3 f.u. for various thicknesses from 30 to 230 nm. The Ga reduces the remanent magnetization and together with the tensile strain causes a stronger PMA. This results in a drastically increased negative effective magnetization for Ga:YIG films, favoring an out-of-plane easy axis.

We also demonstrate that, independent of the thickness and of the substrate orientation [(001) vs. (111)], the perpendicular magnetic anisotropy gradually increases with increasing Ga-content, resulting in a 14 times larger perpendicular anisotropy for 1.3 f.u. Ga-content compared to pure YIG. This allows for easy tuning of the PMA by simply varying the Ga concentration. One advantage of YIG almost remains, i.e. the Gilbert-damping increases only slightly with the amount of Ga.

MA 20.41 Tue 16:30 Poster A

The valence of Ce in Ce-substituted permanent magnets — •Janosch Tasto[1], Benedikt Eggert[1], Yuan Hong[2], William Rigaut[2], Stéphane Grenier[2], Thibaut Devillers[2], Nathan Yutronkie[3], Fabrice Wilhelm[3], Andrei Rogalev[3], Heiko Wende[1], Nora Dempsey[2], and Katharina Ollefs[1] — [1]Univ. of Duisburg-Essen — [2]Institute Néel — [3]ESRF

The current development in our society towards more green energy conversion and electric mobility comes hand in hand with a rising demand in permanent magnets including critical rare-earth (RE) elements. The availability of these elements is often restricted by either political boundaries or limited abundance. Therefore, replacing heavy RE elements with more accessible ones while maintaining the magnetic properties of the compound is essential.

Here, we study the role of Ce as a candidate to replace heavy RE elements by investigating its 4f/5d valence state in different Ce-substituted permanent magnet systems. X-ray absorption spectroscopy was performed on Ce-Co, Ce-Co-Zn, and Nd-Ce-La-Fe-B systems with varying composition examining respective K and $L_{2,3}$ edges of their components. We correlate our spectroscopic findings with the composition and the magnetic properties in order to understand the influence of Ce-substitution on the magnetic properties.

We thank the Toyota Motor Corporation, the French National Research Agency (ANR-22-CE91-0008) and the German Research Foundation (CRC/TRR 270 and CRC 1242) for financial support.

MA 20.42 Tue 16:30 Poster A

Imprinting Magnetic Textures By Geometrical Transformation — •Aman Singh[1,2], Balram Singh[1,2], Yana Vaynzof[1,2], and Volker Neu[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, 01069 Dresden, Germany — [2]Technische Universität Dresden, 01062 Dresden, Germany

The application of magnetic devices largely depends on magnetization patterns and the type and quality of domain walls so control over them is an important step in developing magnetic material systems/devices. We present a simple technique to create different types of magnetization patterns, e.g. alternate out-of-plane up-down domains and in-plane head-to-head and tail-to-tail configurations, by a self-assembled geometrical transformation. This is achieved with the help of a polymer platform which consists of a hydrogel as a swelling layer and a stiff polyimide layer. Upon swelling and un-swelling, the platform transforms reversibly into a multi-winding tube. Depending upon the anisotropy of the magnetic material, regular domain patterns can be created simply by applying a homogeneous magnetic field to the magnetic thin films in the rolled state and then unrolling it. The regular domain patterns imprinted by geometrical transformation (GTMP) are thoroughly characterized by Kerr and magnetic force microscopy, and the corresponding stray field landscape is compared with calculations. By going through the intermediate rolled sample state, this technique also offers the possibility to investigate magnetization processes in 3 dimensions.

MA 20.43 Tue 16:30 Poster A

Signatures of slow magnetization relaxation in current reversal method anomalous Hall effect measurements — Sebastian Beckert[1], Richard Schlitz[2], •Gregor Skobjin[2], Antonin Badura[3], Miina Leiviskä[4], Dominik Kriegner[1,3], Daniel Scheffler[1], Kamil Olejník[3], Eva Schmoranzerová[5], Lisa Michez[6], Vincent Baltz[4], Andy Thomas[1,7], Helena Reichlová[1,3], and Sebastian T. B. Goennenwein[2] — [1]IFMP, TU Dresden, Germany — [2]Department of Physics, University of Konstanz, Germany — [3]Institute of Physics ASCR, Czech Republic — [4]Université Grenoble Alpes, CNRS, CEA, IRIG-Spintec, France — [5]Faculty of Mathematics and Physics, Charles University, Czech Republic — [6]Aix-Marseille Université, CNRS, CINaM, France — [7]IFW Dresden, Germany

Slow magnetization relaxation processes are an important time-dependent property of magnetic materials. We show that a current-reversal based measurement method commonly used in magneto-transport experiments can be harnessed for the quantitative study of slow relaxation processes in magnetic thin films. More specifically, we exploit the anomalous Hall effect response to electrically screen the magnetization relaxation dynamics in micropatterned magnetic thin films. We apply our technique to different thin film materials with perpendicular magnetic anisotropy, as well as a potential altermagnetic compound. We will critically discuss the experimental results, and compare them to lock-in based transport measurements.

MA 20.44 Tue 16:30 Poster A

Investigating antiferromagnetic textures in external magnetic fields — •Sebastian Schultheis[1], Kai Litzius[2], Alexander E. Kossak[3], Julian Skolaut[1], Olena Gomonay[1], and Angela Wittmann[1] — [1]Johannes Gutenberg-Universität, Mainz, Germany — [2]Universität Augsburg, Augsburg, Germany — [3]Massachusetts Institute of Technology, Cambridge, United States of America

In recent years, research on antiferromagnets has received significant attention due to their favorable properties, including robustness to magnetic fields and ultrafast spin dynamics. However, the understanding of the mechanisms of formation of antiferromagnetic domain structure is still limited compared to ferromagnets. Here, we investigate the domain structure of canted antiferromagnets - such as hematite ($\alpha-Fe_2O_3$) - in external magnetic field. The well established method of Photoelectron Emission Microscopy (PEEM) does not allow for imaging the magnetic domain structure in sizable magnetic fields. Thus, here we use Scanning Transmission X-ray Microscopy (STXM) with linearly polarized X-rays to record X-ray Linear Magnetic Dichroism (XMLD) images of the antiferromagnetic ordering via total electron yield. [1] The acquired images were evaluated using methods of image processing to extract quantities describing the change in antiferromagnetic domain structure. Detailed analysis of this data will advance our understanding of the underlying mechanisms of domain structure formation in antiferromagnets.

[1] A. Wittmann et al., Phys. Rev. B 106, 224419 (2022)

MA 20.45 Tue 16:30 Poster A

Superparamagnetic tunnel junctions for neuromorphic computing — •Jonas Köhler[1], Leo Schnitzspan[1,2], Fabian Kammerbauer[1], Gerhard Jakob[1,2], and Mathias Kläui[1,2] — [1]Institute for Physics, Johannes Gutenberg University, 55122 Mainz — [2]Max-Planck Graduate Center Mainz, 55122 Mainz

Superparamagnetic tunnel junctions (SMTJs) are considered promising candidates for building blocks in neuromorphic computing. Due to thermal excitations, the ferromagnetic free layer can switch its magnetization orientation at the nanosecond timescale. The stochastic behavior of the SMTJs allows them to produce true random numbers with encryption-quality randomness [1]. The state probability and the dwell times may be tuned by an external magnetic field or by an applied current via spin transfer torque. When multiple SMTJs are electrically connected, the spin transfer torque leads to an electrical coupling between the MTJs, with the consequence that their stochastic switching becomes correlated [2].

These properties can be used in neural networks, where MTJs can introduce the noise for noise-based learning methods. In comparison to classical approaches, computing implementations using SMTJs can be more energy-efficient.

[1] L. Schnitzspan, et.al., Phys. Rev. Appl. 20, 024002 (2023)

[2] L. Schnitzspan et. al., arXiv:2307.15165 (2023) (in press Appl. Phys. Lett. 123 (2023))

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Molecular beam epitaxial growth of Bi_2Te_3 thin films — •Aeneas Leingärtner-Goth[1,2], Monika Scheufele[1,2], Matthias Althammer[1,2], Hans Huebl[1,2,3], Stephan Geprägs[1], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Technical University of Munich, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Topological insulators such as Bi_2Te_3 are known to exhibit exotic electronic band structures, leading to robust metallic surface states while their bulk spectrum remains gapped [1]. Their intriguing properties make topological insulators candidates for applications in spintronics and quantum computing; their fabrication, however, remains challenging. For example, both anti-site defects and vacancies in Bi_2Te_3 can lead to an enhanced bulk conductivity that overwhelms the contribution of the surface states. Therefore, high-quality Bi_2Te_3 thin films with low bulk defect concentrations are required. Here, we discuss the fabrication of Bi_2Te_3 thin films on (111)-oriented Si substrates by molecular beam epitaxy monitored by reflection high-energy electron diffraction. We characterize the structural and electric properties of these films by high-resolution X-ray diffraction, atomic force microscopy, and electric transport measurements in order to determine the optimal growth conditions for high-quality Bi_2Te_3 thin films.

[1] Y. L. Chen *et al.*, Science **325**, 178-181 (2009)