MA 42: Posters Magnetism I

Time: Wednesday 15:00–18:00 Location: P3

MA 42.1 Wed 15:00 P3

Nonlinear effects in nano-YIG — •Martin Kewenig[1], Morteza Mohseni[1], Julius Balliet[1], Felix Kohl[1], Michael Schneider[1], Björn Heinz[1], Qi Wang[1], Bert Lägel[2], Carsten Dubs[3], Andrii Chumak[4], Philipp Pirro[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Nano Structuring Center, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [3]INNOVENT e.V., Technologieentwicklung, Jena, Germany — [4]Faculty of Physics, University of Vienna, Vienna, Austria

Spin waves show many characteristics, which make them suitable for future information technology. For example, they feature intrinsic strong nonlinear behavior. Since nonlinear effects are important to build logic devices, it is of high interest to understand the underlying mechanism and to study nonlinear effects in nanoscaled devices. We show a nonlinear scattering effect from the fundamental mode to the first and second perpendicular standing spin-wave mode in a micro structured, 85 nm thick Yttrium-Iron-Garnet waveguide. The scattering process has been investigated by frequency- and time-resolved Brillouin-light-scattering spectroscopy. Field- and power-dependent measurements indicate a clear threshold behavior of the investigated phenomenon. This research has been supported by: EU Horizon 2020 research and innovation programme within the CHIRON project (contract number 801055), DFG SFB/TRR 173 Spin+X, Project B01, ERC Starting Grant 678309 MagnonCircuit and DFG (DU 1427/2-1).

MA 42.2 Wed 15:00 P3

Sub-micrometer near-field focusing of spin waves in ultrathin YIG films — •Boris Divinskiy[1], Nicolas Thiery[2], Laurent Vila[2], Olivier Klein[2], Nathan Beaulieu[3], Jamal B. Youssef[3], Sergej O. Demokritov[1], and Vladislav E. Demidov[1] — [1]University of Münster, Münster, Germany — [2]Univ. Grenoble Alpes, CNRS, CEA, Grenoble INP, IRIG-SPINTEC, Grenoble, France — [3]LabSTICC, CNRS, Université de Bretagne Occidentale, Brest, France

We experimentally demonstrate tight focusing of a spin wave beam excited in extended nanometer-thick films of Yttrium Iron Garnet by a simple microscopic antenna functioning as a single-slit near-field lens. We show that the focal distance and the minimum transverse width of the beam can be controlled in a broad range by varying the frequency/wavelength of spin waves and the antenna geometry. The experimental data are in good agreement with the results of numerical simulations. Our findings provide a simple solution for implementation of magnonic nano-devices requiring local concentration of the spin-wave energy.

MA 42.3 Wed 15:00 P3

Bridging magnonics and spin-orbitronics — •Boris Divinskiy[1], Vladislav E. Demidov[1], Sergei Urazhdin[2], and Sergej O. Demokritov[1] — [1]University of Münster, Münster, Germany — [2]Emory University, Atlanta, USA

The emerging field of nano-magnonics utilizes high-frequency waves of magnetization - the spin waves - for the transmission and processing of information on the nanoscale. The advent of spin-transfer torque has spurred significant advances in nano-magnonics, by enabling highly efficient local spin-wave generation in magnonic nanodevices. Furthermore, the recent emergence of spin-orbitronics, which utilizes spin-orbit interaction as the source of spin torque, has provided a unique ability to exert spin torque over spatially extended areas of magnonic structures, enabling enhanced spin-wave transmission. Here, we experimentally demonstrate that these advances can be efficiently combined. We utilize the same spin-orbit torque mechanism for the generation of propagating spin waves, and for the long-range enhancement of their propagation, in a single integrated nano-magnonic device. The demonstrated system exhibits a controllable directional asymmetry of spin wave emission, which is highly beneficial for applications in non-reciprocal magnonic logic and neuromorphic computing.

References:

[1] B. Divinskiy et al., Adv. Mater. 1802837 (2018)

MA 42.4 Wed 15:00 P3

Implementation of the Stimulated-Raman-Adiabatic-Passage mechanism in magnonics — Qi Wang, •Anna M. Friedel, Thomas Brächer, Andrii V. Chumak, Burkard Hillebrands, and Philipp Pirro — Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Kaiserslautern, Germany

The Stimulated Raman Adiabatic Passage (STIRAP) is a process known from atomic physics which describes the population transfer between two states, where direct transitions are dipole forbidden, using a specific coupling scheme to a third state. The STIRAP process has found various applications in many fields of physics [1] and has already been implemented in the field of waveguide optics [2]. We present first results of the magnonic realisation of the STIRAP process. Our demonstrator consists of three, partially curved magnonic waveguides, which are locally coupled via the dipolar stray fields of magnons in well-defined regions of small separation between two neighbouring waveguides. Using micromagnetic simulations, we show that the population of magnons can be transferred between the outer waveguides via the intermediate waveguide. Analogous to the atomic STIRAP process, if the ”counterintuitive” coupling scheme is used, the intermediate waveguide is not excited during the transfer. This implementation of a mechanism known from the field of quantum control and coherent control into magnonic functionalities is one of many quantum-classical analogy phenomena that could be transferred to magnonics.

[1] K. Bergmann et al., J. Phys. B 52, 202001 (2019)
[2] S. Longhi, Laser Photonics Rev. 3, 243 (2009)

MA 42.5 Wed 15:00 P3

Three-magnon scattering in a displaced magnetic vortex — •Lukas Körber[1,2], Katrin Schultheiss[1], Tobias Hula[1], Roman Verba[3], Attila Kákay[1], and Helmut Schultheiss[1,2] — [1]Helmholtz-Zentrum Dresden - Rossendorf, Germany — [2]TU Dresden, Germany — [3]Institute of Magnetism, National Academy of Sciences of Ukraine, Kyiv, Ukraine

In a small ferromagnetic disk which is magnetized in the vortex state, only a discrete set of spin-wave modes exists due the confinement as well as the cylindrical symmetry. When a radial mode is excited above certain threshold power it may decay into two azimuthal spin-wave modes via a process called three-magnon scattering. The three-magnon scattering in such a case has been found to obey certain selection rules which lead for the mode profiles of the secondary waves to be distinct from each other [1]. Here, we study the stability of this process when the cylindrical symmetry is broken by displacing the vortex with an external magnetic field. We find that the selection rules are maintained and three-magnon scattering into two different azimuthal modes persists below the vortex annihilation field. Moreover, we observe the appearance of additional secondary modes which appear for a certain range of external fields and for lower excitation field powers than the regular vortex modes. Financial support of within DFG programme SCHU 2922/1-1 and KA 5069/1-1 is acknowledged.

[1] Phys. Rev. Lett. 122, 097202

MA 42.6 Wed 15:00 P3

Spinwave propagation and mode conversion in an asymmetric YIG fork structure — •Julius Balliet[1], Martin Kewenig[1], Frank Heussner[1], Felix Kohl[1], Bert Lägel[2], Carsten Dubs[3], Andrii Chumak[4], Philipp Pirro[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Nano Structuring Center, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [3]INNOVENT e.V., Technologieentwicklung, Jena, Germany — [4]Faculty of Physics, University of Vienna, Vienna, Austria

Spin waves are collective excitations in the spin system of a magnetic material. They show many characteristics, which make them suitable as data carriers in data processing. A promising device is a spin wave based majority gate consisting of three inputs and one output in a forklike structure. As a foundation to implement such a nanoscale majority gate, the spin wave propagation in a Yttrium-Iron-Garnet fork microstructure was observed via frequency-resolved Brillouin-light-scattering spectroscopy in addition to micromagnetic simulations. Two-dimensional spin wave intensity distributions of the combining area of two inputs show that the spin waves propagate in

beams not parallel to the connecting waveguide which ends in a zigzag intensity profile. This research has been supported by: EU Horizon 2020 research and innovation programme within the CHIRON project (contract number 801055), DFG SFB/TRR 173 Spin+X, Project B01, ERC Starting Grant 678309 MagnonCircuit and DFG (DU 1427/2-1).

MA 42.7 Wed 15:00 P3

First electrical detection of a magnon BEC in bulk-YIG — •Timo B. Noack, Vitaliy I. Vasyuchka, Burkard Hillebrands, and Alexander A. Serga — Fachbereich Physik und Forschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Magnons are weakly ineracting bosonic quasi-particles and therefore they are able to form a Bose-Einstein condensate even at room temperatures. The comparable easy technique of generation of the BEC in magnonic systems, the possibility of its creation at ambient conditions and its potential for the application of this macroscopic quantum state in post-Von-Neumann computing make this research field to a large growing part of the modern magnonics. In this contribution we demonstrate the first measurements of magnon BECs in bulk-sample. A clear threshold of the applied pumping power for the condensation of magnons at the lowest energy state was found. The direct electrical measurement of this lowest state reveals the expected narrow frequency bandwidth and confirmes, thus, the population of a single quantum state. Coincidentally with the sudden narrowing at this treshold a drastic increase in the decay time of the signal can be observed. Financial support of the European Research Council within the Advanced Grant 694709 SuperMagnonics "Supercurrents of MagnonCondensates for Advanced Magnonics" is gratefully acknowledged.

MA 42.8 Wed 15:00 P3

Investigation of parallel parametric pumping processes in individual YIG nanostructures — •Akira Lentfert[1], Björn Heinz[1,2], Morteza Mohseni[1], Michael Schneider[1], Burkard Hillebrands[1], Andrii V. Chumak[3], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Mainz, Germany — [3]Nanomagnetism and Magnonics, Faculty of Physics, University of Vienna, Vienna, Austria

Yttrium iron garnet (YIG) is a unique material with outstanding magnetic properties such as the lowest known spin-wave damping. It is therefore a promising candidate for the application in spin-wave based circuits and logic devices. Nevertheless, the ability to amplify the spin-wave amplitude and to increase the travel distance is crucial for the realization of such spin-wave logic networks. Parallel parametric pumping is a powerful tool in this regard, which allows for the generation and amplification of spin waves while conserving the phase. In this work, we investigate the parallel parametric generation in individual nanosized YIG conduits with lateral dimension down to 50 nm. Time resolved micro-focused Brillouin-Light-Scattering spectroscopy is used to measure the generated spin-wave spectrum directly below the pumping area, and the pumping threshold is extracted. This research has been supported by ERC starting Grant 678309 MagnonCircuits, DFG Grant DU 1427/2-1 and the Graduate School Material Science in Mainz (MAINZ).

MA 42.9 Wed 15:00 P3

Magnon condensation in the presence of magnetoelastic interaction — •Vitaliy I. Vasyuchka[1], Pascal Frey[1], Mio Ishibashi[2], Alexander A. Serga[1], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]Institute for Chemical Research, Kyoto University, Kyoto, Japan

We report on the investigation of the magnon condensation in the presence of the magnetoelastic interaction in different areas of the magnon phase space. Energy spectra of an overpopulated magnon-phonon gas were studied at room temperature in an yttrium iron garnet (YIG, $Y_3Fe_5O_{12}$) film by frequency-, time- and wavevector-resolved Brillouin light scattering (BLS) spectroscopy under different pumping and bias magnetic field conditions. The population of magnon-phonon spectra and its time evolution demonstrate a strong interaction between condensed magnons and accumulated magnetoelastic quasiparticles, when they are located close to each other in the phase space.

Financial support by the European Research Council (ERC) within the Advanced Grant "SuperMagnonics" (Grant agreement No. 694709) is gratefully acknowledged.

MA 42.10 Wed 15:00 P3

Spin-wave packets triggered by ultrashort laserpulses — •Tobias Tubandt[1], Justyna Rychly[2], Jakob Walowski[1], Christian Denker[1], Jaroslav Klos[2], and Markus Münzenberg[1] — [1]Institute of Physics, University Greifswald, Germany — [2]Faculty of Physics, Adam Mickiewicz University Poznań, Polen

The theoretical foundations to magnons and spin-waves has already been established in 1940 by Felix Bloch, yet magnonics itself remains a vivid research field. The advance in nanotechnology and the development of experimental techniques to analyse magnetization dynamics in the recent years bring a growing interest in the search for technologies, which utilize spin-waves to store, carry and process information. We investigate broadband excitations of spin-wave packets by ultrashort laser pulses in magnonic antidot crystals and one-dimensional stripe patterns varying the stripe broadness. The propagation distance in the antidot lattices depends on the direction of the applied magnetic field as well as the surface geometry of the crystal. Additionally, spatially resolved magnetization dynamics measurements on thin CoFeB films reveal that the frequencies of resulting spin-wave modes depend strongly on the distance to the pump center, due to the laser generated temperature profile, which leads to a 0.5 GHz shift in the spin-wave frequency and persists for up to one nanosecond. For the stripe patterns, micromagnetic simulations predict a distance dependent frequency shift. This behavior can be confirmed experimentally.

MA 42.11 Wed 15:00 P3

A novel approach for growing low-loss ferrimagnetic garnet nanofilms — •Christopher Heins, Robert Gruhl, Vasily Moshnyaga, and Henning Ulrichs — 1. Physikalisches Institut, Georg-August-Universität Göttingen, Germany

The ferrimagnetic insulator Yttrium iron garnet (YIG) is a popular material in magnonics due to its ultra-low magnetic damping. Thereby, it is well suited to study fundamental physics like magnon Bose-Einstein condensation, and realize filtering applications in microwave electronics. While liquid phase epitaxy methods allow since many decades to grow YIG films with micrometer thickness, nowadays pulsed laser deposited (PLD) YIG films with thicknesses of few nanometers are in the scientific focus. On this poster we report on such YIG nanofilms, which were grown by metal-organic aerosol deposition (MAD) as an alternative approach. This method allows to synthesize complex oxide films directly from its atomic constituents. Besides characterization of structural and magnetic properties by XRD and SQUID, we use a custom-built stripline Ferromagnetic Resonance setup to determine dynamic magnetic properties. We find a Gilbert damping of about $(6.7\pm0.9)\cdot10^{-4}$, which is comparable with typical PLD grown films. We acknowledge financial support by the DFG within the CRC 1073.

MA 42.12 Wed 15:00 P3

THz spin-wave generation in optically-driven acoustic resonators — •Dennis Meyer, Vitaly Bruchmann-Bamberg, Christopher Heins, Sina Ludewig, Vasily Moshnyaga, and Henning Ulrichs — I. Physical Institute, Georg-August University Göttingen, 37077 Göttingen, Germany

Ultrafast optically-driven coherent THz spin wave sources are of crucial importance for high frequency spintronic applications. However, a monochromatic coherent spin-wave generation for frequencies $f = 0.1 - 6$ THz is hard to achieve using optical methods, which produce rather incoherent or non-monochromatic spin-waves. Magnetoelastic coupling, usually viewed as an undesirable dissipation channel in spintronics, was recently shown to generate spin currents and coherent magnetic oscillations in the low GHz regime. Such experiments, utilizing microwave radiation, are practically restricted to frequencies less than 10 GHz. We propose a novel design to generate THz spin waves by laser excitation of an acoustic nanocavity. The idea is to apply a fs-laser pulse to generate a spectrally broad stress pulse in a metallic transducer layer (β-W or Pt) that passes a ferromagnetic layer (e.g. $La_{0.7}Sr_{0.3}MnO_3$ or CoFeB) featuring significant magneto-elastic coupling. Finally, it reaches a superlattice structure (e.g. $LaMnO_3/SrMnO_3$), which acts as a frequency selective Bragg mirror for phonons. By matching the dispersion of magnons and phonons, energy transfer from the phonon into a magnon mode occurs. We acknowledge financial support by the DFG within project A02 of the CRC 1073 *Atomic scale control of energy conversion*.

MA 42.13 Wed 15:00 P3

Spin Torques in Coupled YIG/Py Heterostructures —

•Carolina Lüthi[1,2], Luis Flacke[1,2], Hans Huebl[1,2,3], Matthias Althammer[1,2], Rudolf Gross[1,2,3], and Mathias Weiler[1,2] — [1]Walther-Meissner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, Germany — [3]Nanosystems Initiative Munich, Germany

Modern spin-wave technology aims to encode and transport information using the electron spin-angular momentum. In this field, the ferrimagnetic insulator yttrium iron garnet (YIG) has numerous applications due to its low intrinsic Gilbert damping. We investigate spin dynamics due to interfacial spin torques in YIG/NiFe thin film heterostructures by broadband ferromagnetic resonance (FMR) spectroscopy. We observe an efficient excitation of perpendicular standing spin waves in the YIG layer, in agreement with our earlier findings [1]. Additionally, for oblique orientations of the external magnetic field and at cryogenic temperatures, we observe exchange-modes which hybridize with the FMR modes of Py and YIG. We study their dynamics as a model system for hybrid excitations in magnetic heterostructures.

Financial support by the DFG via project WE5386/5-1 is acknowledged.

[1] Stefan Klingler *et al.*, Phys. Rev. **120**: 127201 (2018)

MA 42.14 Wed 15:00 P3

Non-linear spin-wave generation at low magnetic bias fields — •Rouven Dreyer, Chris Körner, Niklas Liebing, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics, Von-Danckelmann-Platz 3, 06120 Halle (Saale), Germany

For small magnetic stiffnesses the non-linear spin-wave excitations are not adequately described by Suhl instability processes [1]. It was shown that in this regime spin waves at fractional multiples of the pump frequency (such as $3/2\ \omega$) are excited [1]. Here we demonstrate the $3/2\ \omega$ non-linear spin-wave (NLSW) generation in $Ni_{80}Fe_{20}$ microstructures using different scanning magneto-optical microscopy approaches. A special version time-resolved Kerr microscopy [2] allows for phase-resolved imaging and provides access to the wave vectors of parametrically excited NLSW at $3/2\ \omega$ above the threshold rf-field. The threshold behavior of this type of non-linearities is compared with results from a NV-center photoluminescence microscope using the same sample. Since the NV-center is very small signal averaging in the area of the laser spot is avoided, therefore a lack of phase stability in space and time does not reduce the signal and the NV-centers can be utilized to investigate the NLSW excitation for large wave vectors close to the threshold condition. Our results are further supported by microfocussed Brillouin light scattering (μ-BLS) experiments performed on the same samples. [1] H. G. Bauer et al., Nat. Commun. 6:8274 (2015) [2] R. Dreyer et al., arXiv:1803.04943 (2018)

MA 42.15 Wed 15:00 P3

Sub-wavelength THz measurements of small crystals: chiral Ni_3TeO_6 — •David Maluski[1], Malte Langenbach[1], David Szaller[2], István Kézsmárki[3], Vladimir Tsurkan[3], Sang-Wook Cheong[4], Joachim Hemberger[1], and Markus Grüninger[1] — [1]II. Physikalisches Institut, Universität zu Köln — [2]Institut für Festkörperphysik, Technische Universität Wien — [3]Experimentalphysik V, Universität Augsburg — [4]Department of Physics and Astronomy Rutgers, The State University of New Jersey

For single crystals with dimensions in the mm range, THz spectroscopy faces the problem of diffraction when the wavelength becomes comparable to the sample size. For instance, the transmitted intensity is significantly suppressed with increasing wavelength, hampering a quantitative analysis. We show, however, that the phase of the photons reaching the detector still can be analysed quantitatively, extending the accessible range for THz spectroscopy to lower frequencies. As an example, we study a single domain of chiral Ni_3TeO_6 with circularly polarized light in high magnetic field, establishing the existence of directional dichroism. This effect can be attributed to the chiral and polar structure and the large dynamic magneto-electric susceptibility.

MA 42.16 Wed 15:00 P3

Non-equilibrium spin dynamics and statics enforced by spin currents in ferrimagnetic nanofilms — •Sina Ludewig, Dennis Meyer, and Henning Ulrichs — 1. Physical Institute, Georg-August-University Göttingen, 37077 Göttingen, Germany

On this poster, we report about our investigations of highly non-linear spin dynamics in nanometer-thick Yttrium-Iron-Garnet (YIG) films, induced by means of spin currents, which are generated via the spin-Hall effect. Using micromagnetic simulation we identify a dynamic regime hosting localized, non-propagating solitons, a turbulent chaotic regime, as well as a quasi-static phase featuring a stripe-like magnetization texture, and eventually at largest spin current a homogeneously switched state. To actually realize such dynamics, we propose YIG films grown by metal-organic aerosol deposition, as well as sputtered beta-tungsten (β-W) as a material with large spin-Hall angle. Concerning β-W, we include on this poster our recent progress regarding the reproducible growth of this non-equilibrium structural phase.

We acknowledge financial support by the DFG within the SFB 1073.

MA 42.17 Wed 15:00 P3

Concept of Brillouin light scattering spectroscopy of magnons in optically-induced 2D magnetic landscapes — •Matthias R. Schweizer, Alexander J.E. Kreil, Vitaliy I. Vasyuchka, Georg von Freymann, Alexander A. Serga, and Burkard Hillebrands — Fachbereich Physik und Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany

Brillouin light scattering spectroscopy (BLS) is an important tool for the investigation of spin waves (SW) and their quanta, magnons, in a wide frequency and wave vector ranges. It allows for the measurement of magnon density with high spatial and temporal resolutions.

On the other hand, it has been shown that optically induced magnetization landscapes are a powerful tool to control the propagation dynamics of externally excited spin waves. Furthermore, they can be used to propel a supercurrent spin transport in Bose-Einstein magnon condensates. Such landscapes can be created by using a spatial light modulator (SLM), which is able to project reconfigurable two-dimensional optical intensity patterns on a sample, heating it and thus forming periodic magnetization arrays and graded index structures.

We present a concept for the combination of both techniques, which results in a flexible method for the optical control and observation of two-dimensional magnon dynamics on mesoscopic and microscopic scales.

Support by SFB/TRR 173 Spin+X (project B04) is gratefully acknowledged.

MA 42.18 Wed 15:00 P3

Plasmonic Field Confinement for Ultrafast High-Harmonic Dichroic Microscopy — •Jakob Hagen, Sergey Zayko, Ofer Kfir, and Claus Ropers — 4th Physical Institute, University of Göttingen, Germany

The response of magnetic materials to abrupt laser excitation indicates evidences of intriguing femtosecond dynamics [1]. While a number of spectroscopic techniques were developed to get access and, potentially, unveil the physics behind this phenomenon, the direct observation of nanoscale spin dynamics in real space remains challenging [2] since it requires a nanometric resolution imaging, femtosecond temporal resolution and also nanoscopic excitation. In this study we develop such an excitation to trigger femtosecond spin dynamics, based on plasmonic nanostructures fabricated by electron beam lithography. These structures complement the nanometric imaging resolution using femtosecond pulses of high harmonic radiation [3]. This work would enable versatile sub-wavelength illumination profiles of the magnetic structure and may allow for magnon-selective excitation.

[1] E. Beaurepaire et al., *Phys. Rev. Lett.*, **76**, 22 (1996) [2] C. von Korff Schmising et al., *Phys. Rev. Lett.*, **112**, 217203 (2014) [3] O. Kfir et al., *Sci. Adv.*, **3** (12), eaao4641 (2017).

MA 42.19 Wed 15:00 P3

Study of Ultrafast Magnetization Dynamics in Perovskite Oxide Films by use of Extreme Ultraviolet Light — •Henrike Probst, Christina Möller, Johannes Otto, Cinja Seick, Matthijs Jansen, Sabine Steil, Daniel Steil, Vasily Moshnyaga, and Stefan Mathias — 1. Physikalisches Institut, Göttingen, Germany

Ultrafast spin dynamics has become an active field of research since the seminal work of Beaurepaire in 1996 [1]. Despite numerous experimental and theoretical works, the magnetization dynamics in complex systems such as alloys, multilayers and strongly correlated electron systems are still barely explored.

To investigate ultrafast magnetization dynamics in thin film perovskite oxides, we built up a new element-specific high-harmonic-generation-based magneto-optical Kerr (HHG-MOKE) setup. It allows to apply magnetic fields, B=0-1 T, and to vary the sample temperature, T=4-400 K, to control the magnetic phase of the film.

We will present first element-specific HHG-MOKE data on high quality thin perovskite films prepared by metalorganic aerosol deposition technique.

[1] E. Beaurepaire et al., Phys Rev Lett 76, 4250 (1996).

MA 42.20 Wed 15:00 P3

Finite size effects on the ultrafast remagnetization- and lattice dynamics of FePt — Alexander von Reppert[1], Lisa Willig[1], Jan-Etienne Pudell[1], Steffen Zeuschner[1,2], Gabriel Sellge[3,4], Fabian Ganss[3], Olav Hellwig[3,4], Jon Ander Arregi[5], Voitech Uhlíř[5], Aurelien Crut[6], and •Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam — [2]Helmholtz-Zentrum Berlin, Berlin — [3]Institut für Physik, TU Chemnitz, Chemnitz — [4]Helmholtz-Zentrum Dresden-Rossendorf, Dresden — [5]CEITEC BUT, Brno University of Technology, Brno, Czechia — [6]ILM, Université de Lyon, Villeurbanne, France

We investigate the coupling between the ultrafast lattice and magnetization dynamics of FePt in the $L1_0$ phase after an optical heating pulse, as used in heat assisted magnetic recording. We compare continuous and nano-granular thin films and emphasize the impact of the finite size on both the strain response and the remagnetization dynamics. Our timeresolved MOKE experiments show that the remagnetization dynamics for the single-domain FePt nanograins is dictated by the cooling, whereas it strongly depends on the field-dependent domain-wall motion for the continuous FePt-film. By combining ultrafast X-Ray diffraction and FEM-modeling we show that the concomitant lattice response in both specimen is governed by the varying degrees of in-plane motion for both specimen. We present a versatile two-pulse excitation scheme in which the first laser pulse induces a demagnetization, while the second pulse triggers a strongly magnetization-dependent lattice response in the FePt nanograins.

MA 42.21 Wed 15:00 P3

Ultrafast Photoinduced Spin Dynamics and Transmission Transients in the Strongly Correlated Manganite $Pr_{0.9}Ca_{0.1}MnO_3$. — •Tim Titze[1], Hendrik Meer[1], Birte Kressdorf[2], Andreas Weisser[1], Cinja Seick[1], Henning Ulrichs[1], Dennis Meyer[1], Christian Jooss[2], Daniel Steil[1], and Stefan Mathias[1] — [1]1st Physical Institute, University of Goettingen — [2]Institute for Materials Physics, University of Goettingen

We investigate spin and quasiparticle dynamics of a thin $Pr_{0.9}Ca_{0.1}MnO_3$ (PCMO) film, using time resolved transient transmission and magneto-optical Kerr measurements. A cryostat provides the opportunity to study the temperature-dependent properties of this strongly correlated manganite in a temperature range of 20 K - 300 K. At low temperatures (<100 K) we observe a ferromagnetic phase using TR-MOKE, which can be connected to features observed in transient transmission data. The data shows an initial ultrafast increase in magnetization on a sub-ps timescale, followed by a slower demagnetization within tens of ps. In further transient transmission measurements we observe an ultrafast transmission change within less than a picosecond and a slow 100 ps - 1 ns relaxation component, whose T-dependence hints at a proposed phase transition out of the low-temperature orbitally ordered phase around 200 K.

MA 42.22 Wed 15:00 P3

Time-resolved x-ray magnetic circular dichroism on Co/NiMn and Ni/NiMn bilayers — •Ivar Kumberg[1], Rahil Hosseinifar[1], Sakineh Ghaderi[1], Evangelos Golias[1], Sangeeta Thakur[1], Niko Pontius[2], Christian-Schuessler Langeheine[2], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin Albert-Einstein-Straße 15, 12489 Berlin, Germany

In order to achieve a better understanding of ultrafast demagnetization processes in coupled systems including transport and exchange coupling effects, we studied stacks of adjacent ferromagnetic and antiferromagnetic layers by time-resolved pump-probe x-ray magnetic circular dichroism. Measurements were done using 60 fs laser pump and 100 fs X-ray probe pulses provided by the FemtoSpeX facility at BESSY II. 15 monolayers (ML) Co/24 ML $Ni_{30}Mn_{70}$ and 15 ML Ni/15 ML $Ni_{30}Mn_{70}$ bilayers were grown by molecular beam epitaxy on Cu(001) and growth was monitored by medium-energy electron diffraction and Auger electron spectroscopy.

We interpret our data by using the two- and three-temperature model as well as a phenomenological description following the solution of these models. The aim is to extract the demagnetization times in dependence of temperature, laser fluence, and layer thickness. The demagnetization times are in the range of 100 to 170 fs and follow the expected temperature dependence.

MA 42.23 Wed 15:00 P3

Investigation of ultrafast laser-induced toggle-switching and domain-wall motion in GdFe — •Rahil Hosseinifar[1], Ivar Kumberg[1], Evangelos Golias[1], Sangeeta Thakur[1], Florian Kronast[2], Manfred Albrecht[3], and Wolfgang Kuch[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie, Albert-Einstein-Straße 15, 12489 Berlin, Germany — [3]Institut für Physik, Universität Augsburg, Universitätsstraße 1, 86159 Augsburg, Germany

Using purely optical means to manipulate the magnetization direction is an interesting way to introduce new potential applications in spintronic devices. Excitation of certain materials by femtosecond laser pulses causes magnetization reversal, irrespective of the magnetization direction. Subsequent pulses thus reverse the magnetization back and forth, which is called “toggle switching”. We study 15 nm thin films of ferrimagnetic GdFe alloys with in-plane and out-of-plane easy axes by X-ray magnetic circular dichroism photoelectron emission microscopy (XMCD-PEEM) using the laser at the SPEEM facility at UE49-PGM1 of BESSY II in Berlin. XMCD-PEEM images after individual linearly polarized laser pulses show clear laser-induced magnetization changes. We observe deterministic and local nondeterministic toggle switching for out-of-plane $Gd_{26}Fe_{74}$ films over a considerable range of laser fluences. The in-plane-magnetized $Gd_{21}Fe_{79}$ sample shows lateral displacements of domain walls of up to several μm after laser excitation.

MA 42.24 Wed 15:00 P3

The role of coherent and incoherent phonons for the excitation of standing spin waves — •Steffen Peer Zeuschner[1,2], Marwan Deb[1], Alexander von Reppert[1], Jan-Etienne Pudell[1], Elena Popova[3], Niels Keller[3], Matthias Rössle[2], Marc Herzog[1], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, 14476 Potsdam, Germany — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Wilhelm-Conrad-Röntgen Campus, BESSY II, 12489 Berlin, Germany — [3]Groupe d'Etude de la Matiére Condensée (GEMaC), CNRS UMR 8635, Université Paris-Saclay, 78035 Versailles, France

We present ultrafast X-ray diffraction (UXRD) and magneto-optical Kerr-effect (MOKE) measurements of the ferrimagnetic insulator bismuth-doped yttrium iron garnet (Bi:YIG). We compare the response of direct optical excitation of a Bi:YIG thin film with femtosecond laser pulses to the indirect excitation mediated by a thin metal transducer. In both cases, a coherent phonon wavepacket instantly traverses the Bi:YIG layer as a result of ultrafast deposition of energy. The main difference are incoherent phonons which are stimulated immediately inside the directly excited Bi:YIG layer but diffuse into the Bi:YIG layer on the timescale of hundreds of picoseconds after exciting the metal transducer. We analyze the response of the magnetic system to the coherent and incoherent phonons in the form of ultrafast demagnetization and standing spin waves (SSW). Via the quantitative assessment of the strain we disentangle the combination of heat and sound in the context of ultrafast stimulation of SSWs.

MA 42.25 Wed 15:00 P3

Electron scattering dynamics with anisotropic excitation — •Marius Weber, Kai Leckron, and Hans Christian Schneider — University of Kaiserslautern, Kaiserslautern, Germany

Ultrafast electron scattering plays an important role in different systems with itinerant carriers such as optically excited ferromagnets or transition metal dichalcogenides. While momentum-dependent electron scattering has been studied extensively in optically excited semiconductors [1,2], these studies were confined to isotropic parabolic model band structures. Here, we calculate electronic dynamics at the level of Boltzmann scattering integrals with and without non-Markovian effects, which lead to a broadening of the energy conservation condition following the approach of Ref. [1]. We study how broadening effects influence the dynamics, in particular the behavior of the kinetic energy. In order to treat electronic dynamics in metallic systems, we have developed a numerical solution for the dynamical distribution function depending on the *momentum vector* that is applicable to more realistic band structures. Our approach leads to well-converged dynamics and is capable of treating up to 30^3 k-points in the three-dimensional Brillouin zone. In a first step we investigated the behavior of anisotropic excitation conditions in a single band.

[1] Bonitz et al., Journal of Physics: Condensed Matter. 8(33):6057 (1999)

[2] Haug and Jauho, Quantum Kinetics in Transport and Optics of Semiconductors, Springer, Berlin Heidelberg (2008)

MA 42.26 Wed 15:00 P3

Numerical solution of linearized electron-electron scattering integrals for ultrafast dynamics and transport — •Félix Dusabirane, Kai Leckron, and Hans Christian Schneider — TU Kaiserslautern, Kaiserslautern, Germany

We study electronic dynamics due to electron-electron scattering in the framework of a linearized Boltzmann collision integral for bandstructures with 3-dimensional Brillouin zones. We present a numerical scheme that allows one to obtain excellent conservation of the carrier density over several tens of picoseconds with a limited numerical effort. We benchmark this scheme for parabolic carrier dispersions against quasi 1-dimensional calculations and analytical results [1]. We also discuss how this approach can be extended to calculate electronic scattering contributions for models of hot-electron transport [2].

[1] V. V. Kabanov and A. S. Alexandrov, Phys. Rev. B 78, 174514 (2008).

[2] D. M. Nenno, B. Rethfeld, and H. C. Schneider, Phys. Rev. B 98, 224416 (2018).

MA 42.27 Wed 15:00 P3

Ultrafast magnetization dynamics in TbGd bilayers and the effect of interlayer angular momentum transport — •Markus Gleich[1], Kamil Bobowski[1], Dominic Lawrenz[1], Can Çağincan[1], Niko Pontius[2], Daniel Schick[2], Torsten Kachel[2], Christian Schüssler-Langeheine[2], Björn Frietsch[1], Unai Atxitia[1], Nele Thielemann-Kühn[1], and Martin Weinelt[1] — [1]Fachbereich Physik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin — [2]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Albert-Einstein-Straße 15, 12489 Berlin

We studied the ultrafast magnetization dynamics in TbGd bilayers by XMCD in reflection at the FemtoSpeX facility of BESSY II. The bilayers were epitaxially grown on W(110) and show a two-step demagnetization as observed for Gd and Tb [1-3]. Already few layers of Tb influence the temperature-dependent magnetization of the Gd layer. This interaction depends on the distance to the interface suggesting substantial Gd-Tb spin-coupling. We obtained good agreement between experimental results on ultrafast magnetization dynamics and simulations based on the M3TM [4], which has been extended to account for temperature-dependent thermal conductivity and heat capacity, and most importantly interlayer spin transport.

[1] M. Wietstruk *et al.*, Phys. Rev. Lett. **106**, 127401 (2011).
[2] A. Eschenlohr *et al.*, Phys. Rev. B **89**, 214423 (2014).
[3] K. Bobowski *et al.*, J. Phys.: Condens. Matter **29**, 234003 (2017).
[4] B. Koopmans *et al.*, Nat. Mater. **9**, 259–265 (2010).

MA 42.28 Wed 15:00 P3

Time resolved magnetostriction in itinerant ferromagnet $SrRuO_3$ — Maximilian Mattern[1], •Jan-Etienne Pudell[1], Alexander von Reppert[1], Marc Herzog[1], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Berlin, Germany

We present ultrafast x-ray diffraction (UXRD) measurements of the ferromagnet $SrRuO_3$ using 200 femtosecond x-ray pulses derived from a laser based plasma x-ray source. Optical excitation of a 20 nm $SrRuO_3$ layer by femtosecond laser pulses instantaneously heats up the electron gas. In the paramagnetic phase the deposited energy couples to the phonons and leads to a lattice expansion. In the ferromagnetic phase a part of the deposited energy is transferred to the spin degrees of freedom. This results in a reduced lattice expansion in the ferromagnetic phase due to a pronounced magnetostriction. In the ferromagnetic phase of $SrRuO_3$ the energy transferred from the electrons to the spin system leads to a lattice contraction, whereas heating the phonon system leads to expansion. We model the generated lattice dynamics after laser excitation and analyze the saturation of the spin excitation upon systematic variation of the starting temperature and excitation fluence.

MA 42.29 Wed 15:00 P3

Magnetization dynamics in yttrium-iron-garnet/spin-cross-over bilayer systems — •Rostyslav Serha[1], Michael Schneider[1], Tim Hochdörfer[1], Juliusz Wolny[1], Björn Heinz[1], Carsten Dubs[2], Volker Schünemann[1], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany. — [2]INNOVENT e.V. Technologieentwicklung, D-07745 Jena, Germany

Spin-Cross-Over (SCO) materials are a promising approach to introduce an additional degree of freedom to the field of magnonics. The temperature induced, hysteretic switching of such materials between their diamagnetic and paramagnetic state potentially allows for a temperature-controlled manipulation of the magnetization dynamics in future magnonic devices. Here we investigate the influence of a SCO-layer coated on top of a thin film of yttrium-iron-garnet (YIG) on the magnetic parameters of the bilayer system. Using Vector-Network-Analyzer Ferromagnetic Resonance (FMR) spectroscopy the magnetic parameters, such as the effective saturation magnetization, the Gilbert damping and the linewidth of the FMR are derived at different temperatures. The phase transition of the SCO-material is found to be accompanied by an increased linewidth. The results obtained provide new insight into the behaviour of spin waves in YIG/SCO-systems and open up new avenues in the development of new magnonic logic gates. This research has been supported by: DFG SFB/TRR 173 Spin+X, Project B01, A04.

MA 42.30 Wed 15:00 P3

Relaxation of classical spins coupled to a conduction-electron system with dissipative boundaries — •Michael Elbracht and Michael Potthoff — I. Institute of Theoretical Physics, Department of Physics, Universität Hamburg

The real-time dynamics of a few classical impurity spins locally exchange-coupled to a conduction-electron system is investigated numerically. Starting from a locally excited initial state with a non-collinear impurity-spin configuration, we study the energy and spin dissipation as well as the final relaxation to the ground state. To circumvent finite size effects, a dissipative Lindblad bath is coupled to the system edges which absorbs the outgoing spin excitations. This allows a study of unperturbed real-time dynamics on essentially arbitrary long time scales.

The long-time relaxation of the classical impurity spins is traced as a function of various parameters, such as the exchange interaction or the number and the position of the spins. While the system in fact relaxes completely for an even number of impurity spins, an incomplete relaxation is observed for an odd number, i.e., the system stays in a metastable state. This unconventional behavior is attributed to additional symmetries that dynamically emerge and constrain the time evolution for states with an average energy already close to the ground state energy. The odd-even effect is understood by linearizing the equations of motion close to the manifold of classically degenerate ground states.

MA 42.31 Wed 15:00 P3

Broadband Ferromagnetic Resonance on sputtered YIG and Permalloy thin films — •Luise Siegl, Richard Schlitz, and Sebastian T. B. Goennenwein — Institut für Festkörper- und Materialphysik, Technische Universität Dresden and Würzburg-Dresden Cluster of Excellence ct.qmat, 01062 Dresden, Germany

Broadband ferromagnetic resonance (bbFMR) is a powerful tool to characterize the magnetic properties of magnetic materials. We have assembled a setup and a data evaluation protocol for broadband ferromagnetic resonance measurements for frequencies up to 50GHz. To characterize the setup performance, we measure the magnetic resonance response and the (Gilbert) magnetization damping of thin $Y_3Fe_5O_{12}$ (YIG) and $Ni_{80}Fe_{20}$ (Permalloy) films. We will systematically discuss the corresponding data, and furthermore address our strategy to extract the bbFMR signal from the 'non-magnetic' background. To this end, we take advantage of a background substraction approach put forward recently [1]. Using this approach we find a Gilbert damping of $\alpha = 4.16 \cdot 10^{-4}$ in $Y_3Fe_5O_{12}$ thin films.

We acknowledge funding by the Deutsche Forschungsgemeinschaft (DFG) via SFB1143/C08.

[1] Hannes Maier-Flaig *et al.*, Review of Scientific Instruments **89**, 076101 (2018)

MA 42.32 Wed 15:00 P3

Analysis of Terahertz Emission Profiles from Optically-Excited Magnetic Multilayers — •Dennis Nenno[1,2,3], Rolf Binder[2], and Hans Christian Schneider[1] — [1]TU Kaiserslautern — [2]University of Arizona — [3]Max Planck Institut für Chemische Physik fester Stoffe

Optically excited spin-currents lead to efficient terahertz emission from heavy metals via the inverse Spin-Hall effect [1]. We have developed an approach to simulate the dynamics of hot carriers in metallic multilayers by using a particle-in-cell approach to solve the Boltzmann transport equation. Using this framework, we study the effects of spin-dependent hot-carrier dynamics, as well as terahertz emission from Fe/Pt samples [2]. Our model reliably reproduces experimental findings and we show how the simulation clarifies the importance of the growth conditions [3]. From a genereal transfer-matrix analysis we demonstrate how simple, widely-used relations such as $E \propto \partial j/\partial t$ and $E \propto j$ between the field E and the dynamical charge current j in the emitter arise in the limiting cases of thin and thick layers.

[1] Seifert *et al.*, Nat. Photon. **10**, 483 (2016).
[2] Nenno, Binder & Schneider, Phys. Rev. Appl. **11**, 054083 (2019).
[3] Nenno *et al.*, Sci. Rep. **9**, 13348 (2019).

MA 42.33 Wed 15:00 P3

Engineering the interface of Iron/Platinum spintronic terahertz emitters — •Moritz Ruhwedel[1], Laura Scheuer[1], Rene Beigang[1], Evangelos Th. Papaioannou[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik, TU Kaiserslautern und Landesforschungszentrum OPTIMAS, Kaiserslautern, Germany — [2]Fachbereich Physik, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany

Spintronic Fe/Pt-bilayer systems are considered as a accessible and low-cost approach for the generation of THz radiation. However, the influence of various properties of these bilayer systems is still subject of current research [1-3]. Here, we report on the influence of varied interface conditions for the high energy spin polarized electrons on the emitted THz radiation of the Fe/Pt-bilayer systems. Hereby, a variation of the interface between the Fe- and the Pt-layer is achieved by a variation of the fabrication temperature of the Pt-layer. The resulting transparency of the interface in the low energy regime with respect to the fabrication temperatures is characterized by means of Vector-Network-Analyzer Ferromagnetic Resonance (VNA-FMR) spectroscopy. An increased amplitude of the emitted THz radiation for larger values of the spin mixing conductivity in the low energy regime is observed, which potentially allows for an alternative characterization and further optimization of the spintronic THz-emitters.

[1] G. Torosyan et al., Sci. Rep. 8, 1311 (2018)
[2] E. Papaioannou et al., IEEE Trans. Magn 99, 1-5 (2018)
[3] D. Nenno et al., Sci. Rep. 9, 13348 (2019)

MA 42.34 Wed 15:00 P3

Super-resolution in THz-spectral imaging — •Tristan Winkel[1], Finn-Frederik Lietzow[1], Yuta Sasaki[2], Nina Meyer[1], Jana Kredl[1], Tobias Tubandt[1], Christian Denker[1], Jakob Walowski[1], Shigemi Mizukami[2], and Markus Münzenberg[1] — [1]Institut für Physik, Universität Greifswald, Greifswald, Germany — [2]Advanced Institute for Materials Research, Tohoku University, Sendai, Japan

THz spectroscopy is attractive for scientific research, especially life science [1]. Its wavelength of several hundred μm usually limits its spatial resolution by diffraction. Super-resolution imaging techniques would be required to overcome this limit, while near-field imaging is probably the most feasible.

We investigate THz pulses by excitation of CoFeB/Pt layer stacks [2] and commercial Auston switch emitters with fs laser pulses. 2D motor-stages and LT-GaAs Auston switch detectors combined with Fourier transformation allow for spatially resolved THz spectroscopy.

The spatial resolution using the commercial emitter with focusing optics is half the wavelength. A drastic increase in spatial resolution appears using near-field imaging. A gold test pattern on the spintronic emitter leads to a spatial resolution of less than a tenth of the wavelength. The observation of FWHM of about 10 μm at 1 THz while having FHWM of 3 μm for the corresponding laser excitation using the "knife-edge method" demonstrates the high potential of our approach.

[1] S. K. Mathanker et al., ASABE 56 (2013).
[2] T. Seifert, Nature Photon, 10, pp. 483−488 (2016).

MA 42.35 Wed 15:00 P3

Inverse spin Hall Effect in ferromagnet/heavy metal bilayers with different spin orbit coupling materials and interlayers — •Mohamed Amine Wahada[1], Wolfgang Hoppe[2], Georg Woltersdorf[2], and Stuart S. P. Parkin[1] — [1]Max Planck Institute of Microstructure Physics, Weinberg 2, 06120 Halle (Saale), Germany — [2]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, D-06120 Halle, Germany

Spin pumping combined with the inverse spin Hall Effect (ISHE) is an essential tool in the field of Spintronics that can probe the dynamics of the magnetization of a ferromagnet when this latter is attached to a heavy metal or a spin orbit coupling (SOC) material. By using amplified femtosecond laser pulses, we generate ultrafast spin current pulses into heavy metal layers which are converted, via the ISHE, into ultrafast charge current pulses [1]. An rf probe tip is used to pick up these pulses and detect them in a fast sampling oscilloscope. Although the resultant waveform only has a bandwidth of about 30 GHz quantitatively (compared to the THz bandwidth of the electo-optical sampling method), this quick method provides a qualitative measure of the ISHE. Here, we investigate the influence of an MgO interlayer on the transmission of the spin current depending on the thickness of the oxide. The influence of other metal and oxide interlayers is investigated in terms of the modification of the interface transparency for the spin current pulses. In addition, different SOC materials ranging from heavy metals, topological insulators to Weyl semi-metals are compared. [1] T. Seifert et al. Nature Photon 10, 483-488 (2016)

MA 42.36 Wed 15:00 P3

Spin- and charge transport at THz frequencies in metallic multilayers: A 2-dimensional model — •Marcel Burgard, Dennis M. Nenno, and Hans Christian Schneider — Physics Department, TU Kaiserslautern, Kaiserslautern, Germany

We theoretically investigate spin and charge currents in metallic films and magnetic multilayers. These currents are driven by THz-fields via the inverse spin-Hall effect (ISHE) [1,2]. Frequencies in the THz regime have been shown to drastically alter the transport properties for electrons close to the Fermi energy [3], as they are described by wave-diffusion equations [3,4]. In order to study the impact of screening and ISHE on transport at THz frequencies we extend our model for an effectively one-dimensional calculation [3] to two dimensions and investigate the interaction between currents in different spatial directions.

[1] T. Kampfrath et al., Nature Nanotech 8, 256 (2013).
[2] T. Seifert, et al., Nature Photon 10, 483 (2016).
[3] L. Nadvornik et al., in preparation (2020).
[4] Y.-H. Zhu et al., Phys. Rev. B 78, 054429 (2008).

MA 42.37 Wed 15:00 P3

Piezoelectric Strain Control of Spin-Orbit Torques in CoFeB Thin Films — •M. Filianina[1], J.-P. Hanke[1,3], K. Lee[1], D.-S. Han[1], S. Jaiswal[1,4], G. Jakob[1], A. Rajan[1], Y. Mokrousov[1,3], and M. Kläui[1,2] — [1]Institute of Physics, Johannes Gutenberg University, Mainz, Germany — [2]Graduate School of Excellence Material Science in Mainz, Mainz, Germany — [3]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich — [4]Singulus Technology AG, Kahl am Mainz, Germany

Energy-efficient control of magnetization in nanoscale is fundamental for designing future generation spintronic devices. In recent years current-induced magnetization switching via spin-orbit torques (SOTs), realized in ferromagnet/heavy metal bilayers, has emerged as one of the most promising approaches. The magnitude and the sign of the SOTs can be engineered by adjusting the system parameters. However, the SOTs are set once the device is fabricated, while in the light of potential applications the dynamical control of the SOTs is desired.

Here we demonstrate dynamic control of SOTs in perpendicularly magnetized W/CoFeB/MgO multilayers by electric field-induced strain. We find that modulated by an electric field tensile strain leads to a significant increase of the damping-like (DL) torque, while the compressive strain leads to its decrease. The field-like (FL) torque remains largely unaffected by strain. We compare our experimental results with theoretical ab initio calculations which explain the difference in the response of the FL and DL torques to the strain.

MA 42.38 Wed 15:00 P3

Ab initio calculations on Spin Hall Effect for metallic systems — •Alexander Fabian[1,2], Michael Czerner[1,2], Martin Gradhand[3], and Christian Heiliger[1,2] — [1]Institut für Theoretische Physik, Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16,

35392 Gießen — [2]Zentrum für Materialforschung (LaMa), Justus-Liebig-Universität Gießen, Heinrich-Buff-Ring 16, 35392 Gießen — [3]H.H. Wills Laboratory, University of Bristol, UK

The Spin Hall Effect is a promising effect for use in spintronic devices since it provides a source for spin polarized currents. In order to achieve an efficient conversion of charge current to spin current, different materials have to be investigated. In order to tailor the material properties for efficient usage the properties have to be predicted with a reliable theoretical method. Normally, only the Spin Hall angles and spin conductivities are calculated by theory. On the other hand, optical experiments detect the spin accumulation spatially resolved. In our approach we use a Korringa Kohn Rostoker (KKR) Green's function method with the Keldysh non-equilibrium formalism to calculate a non-equilibrium density under applied bias. From this density we extract the spin accumulation throughout slabs of metal with strong spin orbit coupling for three different systems: Pt, Cu, U. The results of our approach are compared to the results of another KKR approach using the Boltzmann formalism. The origin of the effect should be only of intrinsic nature since there is no contribution of scattering.

MA 42.39 Wed 15:00 P3

Spin Hall Magnetoresistance in normal metal/yttrium iron garnet heterostructures — •E. Karadza[1,2], T. Wimmer[1,2], J. Gueckelhorn[1,2], R. Gross[1,2,3], H. Huebl[1,2,3], and M. Althammer[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), München, Germany

In the field of spintronics, the generation and detection of pure spin currents, i.e. the flow of angular momentum without an accompanying charge current, is an important building block for future spin logic applications. For the generation and detection of pure spin currents the (inverse) spin Hall effect (SHE) in metals with spin-orbit coupling is conveniently utilized. The SHE allows to convert a charge current into a pure spin current. The efficiency of this process is characterized by the spin Hall angle (SHA). Over the last decade many different materials have been investigated to increase the SHA. Here, we present our recent results on determining the SHA via spin Hall magnetoresistance measurements in normal metal (Pt, PtAu)/yttrium iron garnet heterostructures. Our systematic investigation as a function of the normal metal thickness allows us to identify promising materials for efficient pure spin current injection into magnetically ordered insulators. Financial support by the DFG is gratefully acknowledged.

MA 42.40 Wed 15:00 P3

Current induced switching of the Néel vector in CoO(001)/Pt bilayers — •Christin Schmitt[1], Lorenzo Baldrati[1], Romain Lebrun[1], Andrew Ross[1,2], Rafael Ramos[3], Eiji Saitoh[3,4], and Mathias Kläui[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, Germany — [3]WPI-AIMR, Tohoku University, Sendai, Japan — [4]Department of Applied Physics, The University of Tokyo, Japan

Spintronics using antiferromagnets is promising based on intrinsic dynamics in the THz range and absence of stray fields. However efficient electrical writing and reading is necessary. This was shown in the insulating antiferromagnet NiO/heavy metal Pt thin film system (see for instance [1] and references therein), however a signal stemming from non-magnetic switching was also identified [2]. Here, we probe current-induced switching of the Néel vector in Hall crosses patterned on CoO(001)/Pt bilayers. We detect the Néel order by Spin Hall magnetoresistance (SMR) in a Hall-like geometry and switching is induced by current pulses via spin orbit torques. By looking at the switching above and below the Neél temperature in the CoO/Pt bilayer we can separate the "step-like" magnetic [1] and "triangular-like" non-magnetic switching signals [1,2], as the signal related to the antiferromagnetism disappears above Néel temperature. The non-magnetic signal, possibly related to a local annealing process and electromigration in the Pt layer, does not disappear. [1] L. Baldrati et al., PRL 123, 177201 (2019). [2] T. Matalla-Wagner et al., arxiv:1910.8576.

MA 42.41 Wed 15:00 P3

Spin transport in topological Floquet magnon insulator — •Jun-Hui Zheng[1], Roberto Troncoso[1], Walter Hofstetter[2], and Arne Brataas[1] — [1]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway — [2]Institut für Theoretische Physik, Goethe-Universität, 60438 Frankfurt am Main, Germany

In topological insulators, the edge states dominate transport at low temperature. In contrast, topological magnon insulators usually have relatively high-energy edge states. The spin transport is mainly arising from the bulk magnon states. Topological protected edge states are perfect channels for transport due to their robustness against disorder. Enhancing their occupation benefits the efficiency of transport. One method is to excite edges states by photons, a proposed amplification mechanism. Another possibility is to lower the energy of the edge states. Here we show that, by moderately driving the system, we can realize topologically protected edge states with zero energy, and amplify the contribution of spin transport from edge states.

MA 42.42 Wed 15:00 P3

Investigation of phonon interference for acoustically driven spin waves — •Felix Kohl[1], Moritz Geilen[1], Tobias Böttcher[1], Alexandra Nicoloiu[2], Florin Ciubotaru[3], Christoph Adelmann[3], Alexandru Müller[2], Burkard Hillebrands[1], and Philipp Pirro[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]IMT, Bucharest, Romania — [3]IMEC, Leuven, Belgium

We present the investigation of two interfering phonon modes using Brillouin light scattering spectroscopy. For the spin wave excitation by surface acoustic waves it is of great importance to have a valid understanding of the exciting acoustic waves. For this work the surface acoustic waves are generated by interdigital transducers at GHz frequencies, which are commonly used in telecommunication technology. An investigation using BLS microscopy allows for measurements with a high spatial resolution at GHz frequencies. We could observe a characteristic interference pattern of phonon intensity behind the IDT. Wave-vector resolved BLS-measurements allow an explanation of the observed pattern with the interference of the Rayleigh mode and the first Sezawa mode. We acknowledge the support of the EU under H2020 FET Open Project CHIRON (grant agreement no 692519 2018 - 2021).

MA 42.43 Wed 15:00 P3

Growth of RuO_2 thin films and determination of magnetic and transport properties — •Sven Becker[1], Andrew Ross[1,2], Romain Lebrun[1], Lorenzo Baldrati[1], Mathias Kläui[1,2,3], and Gerhard Jakob[1,2] — [1]Institute of Physics, Johannes Gutenberg-University Mainz, 55128 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany — [3]Center for Quantum Spintronics, Department of Physics, Norwegian University of Science and Technology, NO-7491 Trondheim, Norway

Recent theoretical studies predict a novel magnetoresistance effect, present in some collinear antiferromagnets with low crystal symmetry. The so called crystal Hall Effect [1] could permit one to detect electrically not only the direction of the antiferromagnetic Néel order but also its orientation. One candidate for the observation of this phenomena is the metallic antiferromagnet RuO_2. To be able to experimentally measure this predicted effect, one needs to fabricate high quality single crystalline samples with large antiferromagnetic domains. Here we show the growth of high quality thin films of RuO_2 on TiO_2 substrates by pulsed laser deposition. To determine transport properties continuous films have been patterned into Hall bars by e-beam lithography and argon ion etching. Unusual transport properties have been observed in RuO_2/TiO_2 as well as Pt/TiO_2 samples leading us to the conclusion that reductive conditions during the etching process leads to the modification of the TiO_2 substrate surface. [1] L. Šmejkal et al., arXiv:1901.00445 (2019)

MA 42.44 Wed 15:00 P3

Crystallisation of optically thick films of CoxFe(80-x)B20: evolution of the (magneto-) optical and structural properties — •Apoorva Sharma[1], Maria A. Hoffmann[2], Patrick Matthes[3], Olav Hellwig[1,4], Cornelia Kowol[2], Stefan E. Schulz[2,3], Dietrich R. T. Zahn[1], and Georgeta Salvan[1] — [1]Institute of Physics, Chemnitz University of Technology, 09126 Chemnitz, Germany — [2]Center for Microtechnologies, Chemnitz University of Technology, 09126 Chemnitz, Germany — [3]Fraunhofer Institute for Electronic Nanosystems, 09126 Chemnitz, Germany — [4]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Co-Fe-B alloys are highly relevant materials for spintronic applications. In this work, the crystallisation of Co-Fe-B alloys triggered by thermal annealing was investigated by X-ray diffraction techniques and SEM, as well as spectroscopic ellipsometry and magneto-optical Kerr effect spectroscopy for annealing temperatures ranging from 300°C to 600°C. The transformation of ~100 nm thick CoxFe(80-x)B20 films from amorphous to polycrystalline was revealed by the sharpening of spectral features observed in the optical and magneto-optical dielectric functions spectra. The influence of B on the dielectric function was assessed both experimentally and by optical modelling. By analysing the Drude component of the dielectric function, a consistent trend between the charge carrier scattering time/resistivity and the annealing temperature was observed, in agreement with the electrical investigations by means of the four-point-probe method.

MA 42.45 Wed 15:00 P3

Current direction dependent frequency ranges of spin Hall nano-oscillators by adding a magnetic layer — •Toni Hache[1,2], Tillmann Weinhold[1], Yancheng Li[1], Jürgen Fassbender[1,3], Olav Hellwig[1,2], and Helmut Schultheiss[1,3] — [1]HZDR — [2]TU Chemnitz — [3]TU Dresden

Spin Hall nano-oscillators (SHNO) convert dc currents in microwave oscillations of the magnetization. The frequency can be tuned by external magnetic fields, the applied dc current or by injection locking if an additional microwave field is applied to the SHNO. Here, we demonstrate a new approach to extend the frequency range of a SHNO by adding an additional ferromagnetic layer. Moreover, the auto-oscillations can be switched from one to the other ferromagnetic layer by switching the current direction. A constriction-based SHNO consisting of a Py(5nm)/Pt(7nm)/CoFeB(5nm) layer stack with 2 nm Ta as seed and capping layer was used. If a dc current is applied to the structure, a pure spin current is generated by the spin Hall effect in the Pt layer. For a fixed current direction the spin polarization of the pure spin currents entering in the Py and CoFeB layers have opposite directions. Therefore, only one of both ferromagnetic layers experiences a decrease of damping due to the spin transfer torque and can show auto-oscillations of the magnetization. To change the frequency of the SHNO, the dc current direction has to be switched in order to switch the auto-oscillations to the other material with a different frequency range. The authors acknowledge financial support from the Deutsche Forschungsgemeinschaft within programme SCHU 2922/1-1.

MA 42.46 Wed 15:00 P3

Well Balanced Magnetic Gates for Inverted Logic — •Timo Pulch, Daniele Pinna, and Karin Everschor-Sitte — Johannes-Gutenberg Universität

We present an energy efficient solution for inverted logic gates by considering the self-interactions of magnets. Conventional magnetic logic gates have already been showing great results towards scaling and energy efficiency. In this work we present a series of reliable gate designs that are robust against finite temperature effects. The dipolar coupled monodomain magnet designs have been selected according to the fundamental metrics of balance and logical consistency. We argue that energy harvesting of the thermal fluctuations within this model can be used to stabilize the system in the desired logical states. In addition, we go one step further and show that carefully tuned gate structures are able to invert the logical processes of these gates. Invertible logic is a promising approach to solve NP problems.

MA 42.47 Wed 15:00 P3

Designing balanced magnetic logic gates by means of neural networks — •Lukas Holzbeck, Daniele Pinna, and Karin Everschor-Sitte — Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany

Replacing traditional charged-based logic by nanomagnetic logic promises in particular the advantage of non-volatility. However to not lead to erroneous results upon integration to circuits, balanced logic gates are required. So far the search for such logic gates was rather on a trial and error base [cite https://journals.aps.org/prapplied/pdf/10.1103/PhysRevApplied.9.034004]. While such a search is consistently possible with only a few nanomagnets, it becomes rather infeasible for arrangements involving more nanomagnets. Our goal is to employ machine learning to design magnetic logic gates according to developed metrics of well-balanced and logical consistency. We train a neural network on data from static self-interacting systems and aim at finding generalized rules how to construct larger balanced gates and more complex logic gate structures such as the half adder.

MA 42.48 Wed 15:00 P3

Lattice effects accompanying the colossal magnetoresistance effect in $HgCr_2Se_4$ — •Steffi Hartmann[1], Shuai Yang[2], Yongqing Li[2], Jens Müller[1], and Michael Lang[1] — [1]Institute of Physics, Goethe-University Frankfurt, Frankfurt (Main), Germany — [2]Institute of Physics, Chinese Academy of Sciences, Beijing, China

Understanding the origin of large or colossal magnetoresistance (CMR) effects, observed in a wide range of materials, remains a challenging field of research in magnetism. The universal occurrence of electronic and magnetic phase separation in some of these materials has led researchers to suggest a model of percolating magnetic polarons as a possible mechanism to explain the CMR effect. In fact, studies on the semi-metallic CMR material EuB_6 revealed that the magnetically-driven delocalization of charge carriers is accompanied by pronounced lattice distortions [1], consistent with the scenario of percolating nanoscale magnetic clusters. With reference to these results we performed high-resolution thermal expansion and magnetostriction measurements on the half-metallic CMR material $HgCr_2Se_4$, where the paramagnetic to ferromagnetic transition at 105 K drives an insulator-to-metal transition with an 8-orders-of-magnitude decrease of the longitudinal resistivity and a pronounced CMR effect [2]. We will discuss our results with respect to the coupling of the charge and magnetic degrees of freedom to the lattice distortion and compare our results with observations made for other CMR materials. [1] Manna et al., PRL 2014; [2] Guan et al., PRL 2015

MA 42.49 Wed 15:00 P3

Synthesis and crystal growth of (Ni, Fe)2P2X6 (X=S, Se) — •Tamara Holub, Yuliia Shemerliuk, Sebastian Selter, Saicharan Aswartham, and Bernd Buechner — Leibniz Institute for Solid State and Materials Research IFW, Institute for Solid State Research, 01069 Dresden

(NiFe)2P2X6 (X=S, Se) * magnetic material which belongs to the van der Waals family. These compounds are interesting, because of layered two dimensional structure. Here, we report on synthesis and crystal growth of (NiFe)2P2X6 (X=S, Se) by chemical vapor transport (CVT) -technique. Chemical vapor transport is characterized by the reaction of a solid material which volatilizes in the presence of a gaseous reactant and deposits elsewhere or at the cold end of the ampule in the form of single crystal. This (CVT) technique allows us to get high-quality single crystals, at the same time because of the closed system, the evaporation can be controlled. . As grown single crystals are further characterized with x-ray diffraction and SEM\EDX.

MA 42.50 Wed 15:00 P3

Investigating the CMR Effect in $Eu_5In_2Sb_6$ by Means of Nonlinear Transport and Fluctuation Spectroscopy Measurements — •Marvin Kopp[1], Merlin Mitschek[1], Priscila Rosa[2], Lennart Fox[1], and Jens Müller[1] — [1]Institute of Physics, Goethe-University Frankfurt, Frankfurt (Main), Germany — [2]Los Alamos National Laboratory, USA

The structures of Zintl phases illustrate a diversity of clusters, chains and other polyanionic frameworks and show air- and moisture sensitivity due to their components. Recently, air-stable heavy element analogues of the Zintl phases were synthesized as promising candidates for thermoelectric materials [1]. One of these new rare earth analogues is the antiferromagnetic system $Eu_5In_2Sb_6$, which is a narrow band gap semiconductor and shows a colossal magnetoresistance (CMR effect). At the Néel Temperature $T_N = 15\,K$, a sharp drop of the resistivity occurs on lowering the temperature and a strong suppression of the resistivity with applied magnetic field is observed, with magnetoresistance ratios of $-99.9\,\%$ at 15 K and 9 T. In order to test formation and percolation of magnetic polarons as a possible mechanism to explain the large negative magnetoresistive effect we have measured the third harmonic voltage signal giving access to the nonlinear transport, which is found to be non-zero around T_N. In addition we have performed fluctuation (noise) spectroscopy measurements showing a $1/f$-type behaviour of the noise power spectral density over a wide temperature range superimposed by distinct two-level fluctuations around T_N.

[1] J. Mater Chem. C, 2015, **3**, 10518.

MA 42.51 Wed 15:00 P3

strain-induced phase transition in CrI_3 bilayers — •Andrea Leon — Max Planck Institute for Chemical Physics of Solids, Dresden, Germany

Recent reports on ferromagnetic and antiferromagnetic order in different 2D crystal Van der Waals heterostructures, have opened a vast field of possibilities for new physical phenomena and generation of electronic devices which already started to be explored experimentally. Among these materials, layered CrI_3 systems have been of great interest due to the staking dependent magnetism, mechanical/magnetic response under pressure, magnetoelectric and optical properties, between others. Motivated by this, the main goal of this work is to search for new electronic properties of antiferromagnetically coupled CrI_3 bilayer with C2/m symmetry under strain, using DFT calculations and analytic models. We found that strain may be an efficient tool to tune the magnetic phase of the structure. A tensile strain stabilizes the antiferromagnetic phase, while a compressive strain turns the system ferromagnetic. We understood that behavior by looking at the relative displacement between layers due to the strain. We also study the evolution of the magnetic anisotropy, the magnetic exchange coupling between Cr atoms, and how the Curie temperature is affected by the strain.

MA 42.52 Wed 15:00 P3

Induced moment mediated exchange couplings in transition metal systems — •Laszlo Udvardi[1,2] and Laszlo Szunyogh[1,2] — [1]Department of Theoretical Physics, Budapest University of Technology and Economics, Budafoki ut 8, H-1111 Budapest, Hungary — [2]MTA-BME Condensed Matter Research Group, Budapest University of Technology and Economics, Budafoki ut 8, H-1111 Budapest, Hungary

For a reliable description of the temperature dependent magnetic properties of transition metal alloys containing non-magnetic elements or thin magnetic films on non-magnetic substrates the exchange couplings mediated by the non-magnetic atoms must be included. In particular, in order to reproduce the proper gap due to the magnetic anisotropy in the magnetic excitation spectra of thin films, the effect of the induced moments on the substrate atoms must be taken into account. However, the direct inclusion of the exchange interaction between the magnetic and non-magnetic atoms introduces artificial dispersion-less bands in the magnon spectrum. In the present work a new procedure is developed to renormalize the exchange couplings between the magnetic atoms within the framework of the Korringa-Kohn-Rostoker Green-function method. The method is demonstrated for the temperature dependent magnetic anisotropy of ordered FePt alloy and for the magnon spectra of Fe layers on different non-magnetic substrates.

MA 42.53 Wed 15:00 P3

Predictive Design of Induction Coil Geometries using Neural Networks — •Simon Bekemeier[1] and Christian Schröder[1,2] — [1]Bielefeld Institute for Applied Materials Research (BIfAM), Computational Materials Science and Engineering (CMSE), Bielefeld University of Applied Sciences, Department of Engineering Sciences and Mathematics, Interaktion 1, 33619 Bielefeld, Germany — [2]Faculty of Physics, Bielefeld University, Universitätsstraße 25, 33615 Bielefeld, Germany

Nowadays, inductive power transfer is an established technology with its most common application in induction hobs. Such appliances usually use planar coils with homogeneous winding distances. With regard to energy efficiency, comfort and electromagnetic compatibility it is desirable to start from an optimal magnetic field distribution and derive the necessary coil geometry from it.

Unknown, highly non-linear functional relations can be modelled using neural networks with relative ease. In this contribution, we use a deep convolutional auto-encoder to predict the relationship between coil geometries and the respective magnetic fields. To achieve this, the current-path and the coil's magnetic field are presented to the neural network in spatially discretized form. By using the current-path as input and the magnetic field as output, the neural net is trained to find coil geometries, which produce a desired magnetic field. Furthermore, a neural net can be used as a surrogate model to speed up an iterative optimization approach in comparison to using a conventional simulation.

MA 42.54 Wed 15:00 P3

A reverse design methodology for 3-D induction coil windings — •Assja Laas[1] and Christian Schröder[1,2] — [1]Bielefeld Institute for Applied Materials Research (BIfAM), Computational Materials Science and Engineering (CMSE), University of Applied Sciences Bielefeld, Department of Engineering Sciences and Mathematics, Interaktion 1, D-33619 Bielefeld — [2]Faculty of Physics, Bielefeld University, Universitätsstraße 25, 33615 Bielefeld, Germany

In our study we focus on efficient design strategies for three-dimensional induction coils by exploiting an inverse methodology. Compact devices for inductive energy and information transfer require the design of appropriate non-conventional 3-D induction coils. For efficiency and energy reasons the geometry and topology of the coils needs to be adapted to the corresponding application. This is because inside the device there is only restricted space available for mounting the coil and, one is only interested in the near-field characteristics of the generated magnetic field. In our approach, we specify a target field over a certain region and approximate the generating current density through a Fourier series expansion. Because of the ill-posed nature of this problem, we use a Tikhonov regularization with a penalty term in order to calculate the unknown coefficients of the Fourier series expansion. We test our approach by reverse-calculating the windings of simple current carrying coil geometries, such as a circular loop and a linear wire, from their magnetic near-field distribution. Furthermore, we discuss the effect of different penalty terms on the obtained coil geometries and the accuracy of our approximation.

MA 42.55 Wed 15:00 P3

Light Induced Magnetisation Switching in Inversion Breaking Magnetic Materials — •Urmimala Dey[1,2], Oles Matsyshyn[1], and Inti Sodemann[1] — [1]Max Planck Institute for the Physics of Complex Systems, Dresden 01187, Germany — [2]Indian Institute of Technology Kharagpur, Kharagpur 721302, India

We consider the effect of non-linear optical and transport electronic processes on the magnetisation dynamics in materials that break both inversion and time reversal symmetry, with particular focus on the interplay of Berry phases and non-linear processes such as the non-linear Hall effect and the shift and injection currents. In particular we describe an injection current process that is allowed when both of these symmetries are broken and that could facilitate optical control of magnetisation switching processes even with linearly polarised light. We will comment on potential material platforms to experimentally detect these effects.

MA 42.56 Wed 15:00 P3

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

Control of magnetization switching is of critical importance for the development of novel technologies based on magnetic materials. Transitions between stable magnetic states can follow various pathways which are not equivalent in terms of energy consumption and required time. In this study, we propose a general theoretical approach based on the optimal control theory to design pulses of external magnetic field for efficient switching between target magnetic states. The approach involves calculation of optimal control paths (OCPs) for the desired magnetic transition. Following an OCP involves rotation of magnetic moments in such a way that the strength of the external stimulus is minimized, but the system's internal dynamical modes are effectively used to aid magnetization switching. All properties of the switching pulses including temporal and spatial shape can be derived from OCPs in a systematic fashion. Various applications of OCP calculations are presented, including spin-wave assisted magnetization switching in nanowires and nucleation of magnetic skyrmions.

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