MA 67: Poster 4

Time: Friday 9:30–13:00 Location: P2-OG3

MA 67.1 Fri 9:30 P2-OG3

Microwave excitation and optical detection of spin wave beams in NiFe films — •Helmut Körner, Johannes Stigloher, and Christian Back — Institut für Experimentelle und Angewandte Physik, Uni Regensburg, Germany

Only recently, Gruszecki et al. [1] presented an approach enabling the generation of narrow spin wave (SW) beams in thin homogenous nanosized ferromagnetic films by microwave current. Using micromagnetic simulations they showed that the desired beam-type behaviour can be achieved with the aid of a properly designed coplanar waveguide transducer generating a non-uniform microwave magnetic field. The resulting SW beams propagate over distances of several micrometers. Moreover, they state that their approach can be generalized to different magnetization configurations, e.g. forward-volume or Damon-Eshbach (DE) geometry, respectively, and yield multiple SW beams of different width at the same frequency.

Here, we present the results of an experimental study on SW beams propagating in the DE geometry in a 50 nm thick NiFe film by imaging these beams using time-resolved scanning Kerr microscopy (TR-MOKE). We show that it is possible to excite and image (multiple) SWs beams of varying width at the same frequency by carefully tuning the amplitude of the externally applied magnetic field. The shape of the SW beams is inherently determined by the anisotropic nature of the DE SW dispersion for small wave numbers and is also affected by the shape of the coplanar waveguide.

[1] P. Gruszecki et. al., Sci. Rep. 6, 22367 (2016)

MA 67.2 Fri 9:30 P2-OG3

Realization of a macroscopic spin-wave majority gate and its miniaturisation — •Martin Kewenig[1], Tobias Fischer[1,2], Dmytro A Bozhko[1], Ihor I Syvorotka[3], Carsten Dubs[4], Philipp Pirro[1], Burkard Hillebrands[1], and Andrii Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Kaiserslautern, Germany — [2]MAINZ Graduate School of Excellence - Materials Science in Mainz, Mainz, Germany — [3]Department of Crystal Physics and Technology, Scientific Research Company Carat, Lviv, Ukraine — [4]INNOVENT e.V. Technologieentwicklung Jena, 07745 Jena, Germany

Spin-wave logic devices offer large advantages compared to modern CMOS-based elements. An example for such a logic element is the majority gate. In this contribution, we present the investigation of a macroscopic spin-wave majority gate device made from a YIG film. We examine the spin-wave propagation by means of microwave techniques. The operation of the device as a majority gate was proven - the output phase of the signal was defined by the majority of the input phases. Additional time-resolved measurements have shown that the device can switch logic output within approximately 11 ns. In order to scale down spin-wave majority devices we fabricate microstructured combiner structures made from a 100 nm thick YIG film and examine the spin-wave transmission and reflection of different combiner structures by using Brillouin light scattering microscopy. This research has been supported by: EU-FET Grant InSpin 612759, ERC Starting Grant 678309 MagnonCircuit, and DFG (DU 1427/2-1).

MA 67.3 Fri 9:30 P2-OG3

Spatial resolved mapping of spin-wave modes in YIG film excited by an antenna — •Rouven Dreyer, Niklas Liebing, and Georg Woltersdorf — Martin Luther University Halle-Wittenberg, Institute of Physics, Halle(Saale), Germany

Spin-wave propagation in magnetic materials may in the future allow to transmit and process information in an energy-efficient manner. Yttrium Iron Garnet (YIG) is one of the most interesting materials for spin wave based microwave devices due to its low Gilbert damping parameter and the correspondingly large spin wave propagation length. Phase resolved imaging of spin wave excitations is possible by time resolved Kerr microscopy. Here, we present the imaging of Damon-Eshbach and backward volume spin-wave modes in a 200 nm YIG film. Our experiments allow to determine the spin-wave dispersion for different configurations of in-plane wave vector and magnetization. Different antenna structures for spin-wave excitations are investigated.

MA 67.4 Fri 9:30 P2-OG3

Spin Wave Phase Shift upon Reflection — •Johannes Stigloher[1], Takuya Taniguchi[2], Martin Decker[1], Helmut S. Körner[1], Takahiro Moriyama[2], Teruo Ono[2], and Christian H. Back[1] — [1]Department of Physics, Regensburg University, 93053 Regensburg, Germany — [2]Institute for Chemical Research, Kyoto University, Uji, Kyoto 611-0011, Japan

In the experiments presented here, our main observation is a phase shift between incoming and reflected spin waves at an interface between a Permalloy film and a dielectric. Plane spin waves in the dipolar regime are excited by a microwave antenna. By design, the spin waves hit the edge of the film at an angle. An external field is used to tune the wave vector amplitude. It is applied in-plane and aligned parallel to the interface in order to avoid static demagnetizing effects. We detect spin waves by means of a time-resolved scanning Kerr microscope that allows us to directly image the wave fronts [1]. By fitting the interference pattern of incoming and reflected waves, we are able to extract the phase shift in real space. The origin of this shift can be attributed either to an effect similar to the Goos-Hänchen shift in optics or to a finite time delay between the waves. The effect might be used to characterize the interface [2].

[1] J. Stigloher et al. Physical Review Letters, 117, 037204 (2016)
[2] Yu. S. Dadoenkova et al. Applied Physics Letters, 101, 042404 (2012)

MA 67.5 Fri 9:30 P2-OG3

Nanotubes, a novel layout for magnonic applications. — •Jorge A. Otálora[1], Jürgen Lindner[2], Kornelius Nielsch[3], Pedro Landeros[4], and Attila Kákay[3] — [1]Departamento de Física, CEDENNA, Universidad Santiago de Chile, USACH, 9170124 Santiago, Chile — [2]HZDR, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [3]Institute of Metallic Materials at the Leibniz Institute for Solid State and Materials Research, IFW, 01069 Dresden, Germany — [4]Departamento de Física, Universidad Técnica Federico Santa María, Avenida España 1680, Casilla 110-V, Valparaíso, Chile

The knowledge of mechanisms and architectures for controlling spin waves in ferromagnetic systems can be exploited within novel electronic devices. In this context, magnonic devices are proposed in the fields of signal processing, data computation as well as information transfer. In this work we propose a novel system that will significantly foster the endeavor, namely magnetic nanotubes. Here, we highlight their tunable and non-reciprocal spin wave properties. Their curvature-induced nonreciprocity is significant and is present not only in the SWs dispersion, but also manifests itself via a wavevector-dependent absorption leading to the difference in the extinction length of counter-propagating SWs along the tube length[1]. The non-reciprocity can be controlled with application of weak DC external magnetic fields along the tube's large axis. Our findings suggest that magnetic nanotubes can be exploited as a novel layout for flexible and reconfigurable magnonic circuits.[1]J.A. Otálora, et. al., Phys. Rev. Lett. 117, 227203 (2016)

MA 67.6 Fri 9:30 P2-OG3

The Transition from a Thin Film to a Full Magnonic Crystal and the Role of the Demagnetizing Field — •Manuel Langer[1,2], Falk Röder[1,2,3], Rodolfo A. Gallardo[4], Tobias Schneider[1,5], Sven Stienen[1], Christophe Gatel[3], René Hübner[1], Kilian Lenz[1], Jürgen Lindner[1], Pedro Landeros[4], and Jürgen Fassbender[1] — [1]HZDR, Dresden — [2]TU Dresden, Dresden — [3]CEMES-CNRS, Toulouse, France — [4]USM, Valparaíso, Chile — [5]TU Chemnitz, Chemnitz

The transition from a film to a full magnonic crystal is studied by sequentially ion-milling a 40 nm Ni80Fe20 film. The spin-wave resonances of each stage are detected by ferromagnetic resonance for both in-plain field main axes. Theoretical calculations and micromagnetic simulations yield the individual mode profiles, which are analyzed in order to track changes of the mode character. The latter is strongly linked to the evolution of the internal demagnetizing field. It's role is further studied by electron holography measurements of a hybrid magnonic crystal with 10 nm deep surface modulation. The complex effects of mode coupling, mode localization and anisotropy-like contributions by the internal field are unraveled. Simple transition rules from the nth film mode to the mth mode of the full magnonic crystal are formulated.

MA 67.7 Fri 9:30 P2-OG3

Non-reciprocal spin-wave edge modes — •Philipp Pirro, Qi Wang, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany

Non-reciprocal spin waves modes like the magneto-static surface wave (aka Damon-Eshbach mode) are well known phenomena based on the structure of the magnetic dipol-dipol interaction. By micromagnetic simulations, we show how these modes can be used to construct out-of-plane magnetized magnonic systems with chiral edge modes. By introducing defects in our structures, we investigate the protection of these unidirectional modes against back scattering. Interestingly, the exchange interaction has an important effect on the scattering characteristics since it influences the profiles and the frequency spacing of the individual modes. Based on these findings, we design non-reciprocal spin-wave elements which can be used in future magnonic logic elements as spin-wave isolators or circulators.

MA 67.8 Fri 9:30 P2-OG3

Non-Linear Spin-Wave Dynamics in Magnetic Vorticies — •Kai Wagner[1,2], Franziska Wehrmann[2], Friedrich Zahn[2], Attila Kákay[1], and Helmut Schultheiss[1,2] — [1]HZDR, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]TU Dresden, D-01062 Dresden, Germany

Non-linear magnetisation dynamics in micron sized Permalloy disks in the vortex state are investigated by Brillouin-Light-Scattering Microscopy and micromagnetics. To study the spectral, temporal and spatial spin-wave dynamics, a homogeneous and continuous out-of-plane pumping field is applied. For low pumping powers we observe discrete radial modes, as expected for the linear regime and homogeneity of the pumping field. However, high pumping powers lead to multiple magnon scattering, as also observed in [1] for stripe geometries. This results in complex spectra with a multitude of simultaneously occurring power dependent spin-wave frequencies, which are different from the excitation frequency. This can not be explained by simple transition rules known for spin waves in thin films. Under high pumping powers the spin-wave spectra of the vortex state in micron disks appear to be nearly continous. Hence, the conservation of energy can be easily satisfied. Therefore we believe, the corresponding rules for momentum and angular momentum conservation in these scattering processes impose sharp power dependent constraints on the possible scattering processes. [1] R. E. Camley, Phys. Rev. B **89**, 214402 (2014)

MA 67.9 Fri 9:30 P2-OG3

Spin waves in magnetic films driven by optical pulses at high repetition rates — •Manuel Jäckl[1], Vladimir I. Belotelov[2,3], Ilya A. Akimov[1,4], Igor V. Savochkin[2], Dmitri R. Yakovlev[1,4], Anatoly K. Zvezdin[3,5], and Manfred Bayer[1,4] — [1]Experimentelle Physik 2, TU Dortmund, 44221 Dortmund, Germany — [2]Lomonosov Moscow State University, 119991 Moscow, Russia — [3]Russian Quantum Center, Skolkovo, 143025 Moscow, Russia — [4]Ioffe Institute, Russian Academy of Sciences, 194021 St. Petersburg, Russia — [5]Moscow Institute of Physics and Technology, Moscow Region 141700, Russia

We excite magnetization precession in bismuth-substituted iron garnet (BIG) films by a train of circularly polarized fs-laser pulses with a high repetition rate of 1 GHz which is faster than the decay rate of the oscillation. This periodic pumping establishes a quasi-stationary source of spin waves (SW), namely a coherent magnon cloud from which SWs are emitted. With this approach we generate spectrally narrow SWs, so they can propagate over long distances, traceble up to almost $100\,\mu$m, propagating with a pronounced directionally. Furthermore we can increase the amplitude by an enhancement factor of up to one order of magnitude by synchronizing its frequency with the pulse repetition rate.

MA 67.10 Fri 9:30 P2-OG3

Imaging of conversion between different spin wave modes in thermal landscapes with micro-structured induction loops — •Rick Assmann[1], Marc Vogel[1], Andrii V. Chumak[1], Burkard Hillebrands[1], and Georg von Freymann[1,2] — [1]Department of Physics and State Research Center OPTIMAS, University of Kaiserslautern, Erwin-Schroedinger-Str. 56, 67663 Kaiserslautern, Germany — [2]Fraunhofer-Institute for Physical Measurement Techniques IPM, Fraunhofer-Platz 1, 67663 Kaiserslautern, Germany

Spin wave propagation in thin ferrimagnetic films (YIG) can be described as wave propagation, following in most cases the well-known laws of optical propagation, e. g., Snell's law of refraction [Phys. Rev. Lett. 117, 037204 (2016)]. In contrast to optical materials, the dispersion relation of spin waves strongly depends on the direction of the external magnetic field. For in-plane magnetization backward volume magnetostatic spin waves (BVMSW) as well as magnetostatic surface spin waves (MSSW) can be excited, although situated at different frequency regions. A specially designed coplanar waveguide allows to excite spin wave beams [Sci. Rep. 6, 22367 (2016)]. Inducing a beam-splitter via thermal landscapes [Nature Physics 11, 487 (2015)] leads to a redirection of the beam and, hence, to a conversion from BVMSW to MSSW. This conversion and propagation can be observed with micro-structured induction loops, which are scanned over the sample. We compare our experimental results with micromagnetic simulations.

Financial support by DFG collaborative research center SFB/TRR 173 "Spin+X" (project B04) is gratefully acknowledged.

MA 67.11 Fri 9:30 P2-OG3

Magnetic domains in FePt thin films for magneto-ionic effects — •Jonas Zehner[1], Sebastian Fähler[1], Rudolf Schäfer[1], Christine Damm[1], Liu Yang[1,2], Kornelius Nielsch[1], and Karin Leistner[1] — [1]Leibniz-Institut für Festkörper- und Werkstoffforschung Dresden, Deutschland — [2]Technische Universität Dresden, Deutschland

The manipulation of the magnetic properties by an external electric instead of magnetic field is highly interesting from a fundamental and technological point of view. Recently, large reversible voltage-induced changes of interfacial magnetism have been achieved by exploiting electrochemical reactions and denominated magneto-ionic effect [1, 2]. These results indicate that magneto-ionic changes of the magnetic microstructure are possible.

We investigate FePt thin films with regard to the evolution of a magnetic microstructure suitable for the observation of magneto-ionic effects. FePt films (4 nm) were pulsed laser deposited and L10 ordering achieved. Magnetic domain observation by Kerr microscopy revealed two fundamentally different domain characteristics. Large non equilibrium domains are observed in FePt films with increased anisotropy. In contrast, stable bubble like domains are found in the films with lower anisotropy.

First approaches towards electrochemical in situ Kerr microscopy were achieved on FePt thin films. Results showed electrochemical functionality and the possibility of magnetic domain observation through a transparent counter electrode and an electrolyte.

MA 67.12 Fri 9:30 P2-OG3

Structural and Magnetic Properties of FePt-Mn Thin Films — •Matthias Riepp[1], Nataliia Safonova[2], and Manfred Albrecht[2] — [1]Deutsches Elektronen Synchrotron (DESY), Notkestraße 85, 22607 Hamburg, Germany — [2]Institute of Physics, University of Augsburg, 86159 Augsburg, Germany

Systematic investigations of the influence of Mn on the L_10 - phase formation, texture and magnetic properties of tri-layered FePt/Mn/FePt thin films were conducted. The layered films were magnetron sputtered on thermally oxidized Si substrates at room temperature and post annealed via rapid thermal annealing at temperatures ranging from 650° C - 800° C for 30 s in N_2 atmosphere. Pronounced formation of L_10 (001)-textured grains with large perpendicular magnetic anisotropy was observed for Mn concenrations up to 10 at. % particularly at annealing temperatures above 750° C. Only for Mn concentration of 20 at. % a slight reduction of the saturation magnetization and enhanced coercivity were observed.

MA 67.13 Fri 9:30 P2-OG3

Magneto-optic investigation of spin-orbit torques in metallic bilayers — •Robert Islinger, Martin Decker, Johannes Stigloher, Martin Buchner, and Christian Back — Universität Regensburg, Deutschland

We study the spin-orbit torque (SOT) generated when applying a current to micrometer-sized ferromagnetic metal/heavy metal (FM/HM) stripes. We use the magneto-optic Kerr effect in a static experiment. A polarized laser beam is used to probe the out-of-plane component of the magnetization while scanning across the sample [1]. When applying an alternating current to the stripe, the equilibrium position of the magnetization changes which we detect magneto-optically. The field generated by the SO-interaction switches sign when inverting the equilibrium direction of the magnetization using an externally applied magnetic field while the contribution from the current induced Oersted field remains unchanged. Subtracting the detected voltage signals give access to the magnitude of the SOT. The material-related SOT coefficient beta can be derived and is compared for different FM/HM systems. Temperature dependent measurements down to 10K are performed to provide an insight into the temperature behavior of the SOTs. [1] Fan et al. Quantifying interface and bulk contributions to spin-orbit torque in magnetic bilayers, Nat.Comm 5, 3042 (2014)

MA 67.14 Fri 9:30 P2-OG3

Spin Hall effect in topological crystalline insulators Pb1-xSnxTe — •Jue Huang[1], Kai Chang[1,2], and Stuart Parkin[1] — [1]Max Planck Institute of Microstructure Physics, 06120 Halle, Germany — [2]Department of Physics, Tsinghua University, 100084 Beijing, China

The development of spintronics devices currently drives much interest for the widespread applications in memory and logic devices. Therefore, it requires to search materials which can provide more efficient magnetization manipulation. Besides heavy-metal/ferromagnet bilayer materials, topological insulator bismuth selenide (Bi2Se3) is also reported to have large spin torque ratio [1]. We propose that the topological crystalline insulators (TCI) Pb1-xSnxTe, in which the surface exhibits even number of Dirac cone states and topologically protected by crystal symmetry, are potential candidates for spintronics technology. By growing (001) and (111) Pb1-xSnxTe thin films with molecular beam epitaxy (MBE) and measuring spin torque ferromagnetic resonance (ST-FMR) of these thin films, we study the spin Hall effect.

[1] Mellnik A. R., Lee J. S., et al., Nature 511, 449-451, 2014.

MA 67.15 Fri 9:30 P2-OG3

Interface optimization for spin Hall magnetoresistance experiments — •Saki Matsuura[1,2], Matthias Althammer[1,2], Stephan Geprägs[1], Hans Huebl[1,2,3], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TU München, Garching, Germany — [3]Nanosystems InitiativeMunich (NIM), München, Germany

The concept of pure spin currents, i.e. the net flow of spin angular momentum without an accompanying charge current, triggered the discovery of interesting new effects. Among these the spin Hall magnetoresistance (SMR) is present in ferromagnetic insulator (FMI) and normal metal (NM) bilayers, originating from the combined action of spin Hall and inverse spin Hall effect in the NM. The experimental fingerprint of the SMR is a characteristic dependence of the NM's resistivity on the magnetization orientation of the FMI. The SMR magnitude crucially depends on the transfer of a pure spin current accross the FMI/NM interface. We here systematically investigate the SMR in yttrium iron garnet (YIG)/Pt heterostructures, prepared by ex-situ and in-situ methods. To this end, we carried out angle-dependent magnetoresistance measurements and analyzed the SMR as a function of temperature and magnetic field strength. Our results show that for a sizeable SMR in ex-situ samples a suitable cleaning process of the YIG surface prior to the deposition of the Pt is crucial.

MA 67.16 Fri 9:30 P2-OG3

Growth, structural characterisation and magnetotransport measurements in Mn_3Ir thin-films — •James M Taylor[1,2], Edouard Lesne[1], Fasil Kidane Dejene[1], Claudia Felser[2], and Stuart S P Parkin[1] — [1]Max Planck Institute for Microstructure Physics, D-06120 Halle, Germany — [2]Max Planck Institute for Chemical Physics of Solids, 01187 Dresden, Germany

Mn_3Ir antiferromagnetic thin-films, previously utilized to exchange pin ferromagnetic layers in spin valve devices, have recently attracted renewed attention for applications in spintronic devices due to theoretical predictions of a large Berry curvature driven anomalous Hall effect and the observation of a facet-dependent spin Hall effect. Large spin Hall angles of up to $\theta_{SH} = 0.2$ have been measured. Here we report the growth of highly-textured thin-films of Mn_3Ir and their structural characterisation. Techniques such as X-ray diffraction and atomic force microscopy demonstrate films grown in both (001) and (111) orientations with roughnesses of less than 1nm. Antiferromagnetic properties of the films were studied using SQUID magnetometry and X-ray magnetic circular dichroism, as well as exchange biasing to adjacent NiFe ferromagnetic layers. Large values of exchange bias field were obtained, up to $H_{Ex} = 306$ Oe, demonstrating the antiferromagnetic quality of the films. We extended our investigation to study electrical transport in lithographically patterned Mn_3Ir thin-films, including magnetotransport and microwave-frequency measurements.

MA 67.17 Fri 9:30 P2-OG3

Auto-oscillations in double constriction Spin-Hall nano-oscillators — •Toni Hache[1], Kai Wagner[1,2], Sri Sai Phani Kanth Arekapudi[1,3], Tobias Hula[1], Olav Hellwig[1,3], Jürgen Lindner[1], and Helmut Schultheiss[1,2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institut für Ionenstrahlphysik und Materialforschung — [2]Technische Universität Dresden — [3]Technische Universität Chemnitz

Spin-Hall nano-oscillators (SHNOs) are modern auto-oscillation devices. Their simple geometry allows for an optical characterization by Brillouin-Light-Scattering microscopy (μBLS) at room temperature. Here we report on the observation of auto-oscillations in constriction based SHNOs. These are devices where the current density is increased locally due to lateral confinement. Hence, the spin current generated by the spin Hall effect can create well defined hot-spots for auto-oscillations. We present μBLS measurements of auto-oscillations in $Co_{60}Fe_{20}B_{20}$(5 nm)/Pt(7 nm) based samples with two interacting, neighbouring nano-constrictions. The precession amplitude in these samples can be driven far from equilibrium, resulting in clear nonlinear signatures in the spin-wave spectra. The spatial distributions of the observed modes and current dependencies are shown.

The authors acknowledge financial support from the Deutsche Forschungsgemeinschaft within programme SCHU 2922/1-1.

MA 67.18 Fri 9:30 P2-OG3

Structural insight into spin-orbit effects in metal-oxide/Co/Pt sandwiches — •Martin Kopte[1], T. Kosub[1], U. K. Rössler[2], R. Schäfer[2], A. Kákay[1], F. Radu[3], O. G. Schmidt[2], J. Lindner[1], J. Fassbender[1], and D. Makarov[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf e.V., Germany — [2]Leibniz-Insitut für Festkörper- und Werkstoffforschung, Dresden, Germany — [3]Helmholz-Zentrum Berlin für Materialien und Energie, Germany

Novel spinorbitronic devices require a subtle control of spin-orbit effects such as Dzyaloshinskii-Moriya interaction (DMI), spin orbit torques (SOT) and magnetoresistance effects. Here we study the impact of interface properties on the strength of these effects in out-of-plane magnetised metal-oxide/Co/Pt sandwiches. The interface-induced DMI in samples prepared with chromium oxide as the metal oxide layer is quantified by using several approaches. A detailed structural investigation of these samples as well as a comparison to the literature data of samples capped with e.g. magnesium or aluminum oxide show that the DMI strength is predominantly determined by the quality of the Pt/Co interface. Within the accuracy of the experimental data at hand we do not find evidence for a recently predicted Rashba-like contribution of the metal-oxide/Co interface to the DMI strength. Quantification of SOT by harmonic analysis of magnetoresistance data provides complementary insight into the crucial structural dependence of spin-orbit effects. Our experimental data and analysis demonstrate the impact on DMI and SOT, and the possibility to tune these effects, by microstructural details in asymmetric layer stacks.

MA 67.19 Fri 9:30 P2-OG3

Time-resolved scanning electron microscopy with polarization analysis — •Fabian Kloodt[1], Robert Frömter[1,2], Philipp Staeck[1], Axel Frauen[1], Susanne Kuhrau[1], and Hans Peter Oepen[1,2] — [1]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

We demonstrate the feasibility of investigating periodically driven magnetization dynamics in a scanning electron microscope with polarization analysis based on spin-polarized low-energy electron diffraction [1]. With the present setup [2], analyzing the time structure of the scattering events, we obtain a temporal resolution of 700 ps, which is demonstrated by means of imaging the field-driven 100 MHz response of a vortex in a soft-magnetic FeCoSiB square. Owing to the efficient intrinsic timing scheme, high-quality movies, giving two components of the magnetization simultaneously, can be recorded on the time scale of hours. The present state of the method, limitations and the development potential will be discussed.

[1] R. Frömter, Appl. Phys. Lett. 108, 142401 (2016).
[2] R. Frömter, Rev. Sci. Instrum. 82, 033704 (2011).

MA 67.20 Fri 9:30 P2-OG3

Calorimetric Experiments on Fe/W(110) using SP-STM — •Hermann Osterhage, Cody Friesen, and Stefan Krause — Universität Hamburg, Department of Physics, Jungiusstrasse 11A, 20355

Hamburg, Germany

The Seebeck effect provides the possibility to use waste heat to drive electric devices. Combined with progressing miniaturisation this offers a chance to increase the efficiency of future circuits.

In our experiment, we use spin-polarized scanning tunneling microscopy (SP-STM) to investigate the magneto-Seebeck tunneling on a very local scale. While the sample is at a temperature of $T = 50\,\mathrm{K}$, we heat the SP-STM tip by laser irradiation. The resulting thermovoltage between tip and sample is countered by an external bias, yielding zero tunneling current [1]. From the theoretical model of the tunneling process in STM, a proportionality between thermovoltage and tip-sample separation is expected [2]. Experimental results on the Fe/W(110) surface will be shown and compared to this model in terms of the tip-sample separation dependent thermovoltage, and the temperature difference between tip and sample.

[1] D. Hoffmann *et al.*, J. Electron. Spectrosc. Relat. Phenom. **109**, 117 (2000).
[2] J. A. Støvneng *et al.*, Phys. Rev. B **42**, 9214 (1990).

MA 67.21 Fri 9:30 P2-OG3

SEMPA imaging of magnetic spin configurations and manipulation by spin currents — •Daniel Schönke[1], Pascal Krautscheid[1,2], Maike Lauf[1], Benjamin Krüger[1], Robert M. Reeve[1], and Mathias Kläui[1,2] — [1]Institut für Physik, Johannes Gutenberg-Universität, 55099 Mainz, Germany — [2]Graduate School of Excellence Materials Science in Mainz, 55128 Mainz, Germany

Control of the magnetic configuration of nanoscale structures is vital for spintronic device applications. The initial magnetic state is mainly set by material parameters and geometry, while manipulation can be realized using spin-transfer and spin-orbit torques. Scanning electron microscopy with polarization analysis (SEMPA) is a powerful imaging technique to investigate these effects with high resolution and surface sensitivity. We demonstrate how specific domain wall types can be tailored in wires by choosing the dimensions [1] and via geometrical confinement at notches. For the vortex state in disks, spin currents are then employed to manipulate the vortex core, with the imaged displacement related to the non-adiabatic torque [2,3]. By rare earth Dy-doping, the damping can be changed and the resulting change of the non-adiabaticity can be probed and compared to the theory [3]. Direct imaging of spin accumulation would be a next step, however remains challenging due to the low signal and other current-induced effects [4]. [1] P. Krautscheid et al., J. Phys. D: Appl. Phys. 49, 425004 (2016). [2] L. Heyne et al., Phys. Rev. Lett. 105, 187203 (2010). [3] A. Bisig et al., Phys. Rev. Lett. (in press 2016), arxiv:1511.06585 [4] P. Riego et al., Appl. Phys. Lett. 109, 172402 (2016).

MA 67.22 Fri 9:30 P2-OG3

High magnetic field gradient tips for single spin resonance imaging — •Philipp Scheiger, Thomas Oeckinghaus, Rainer Stöhr, Amit Finkler, and Jörg Wrachtrup — 3. Physikalisches Institut, Universität Stuttgart

Due to its high sensitivity to small magnetic fields at room temperature, the nitrogen-vacancy center (NV center) in diamond is a promising tool for resonance imaging of single electron spins in molecules using atomic force microscopy (AFM) techniques under ambient conditions. Using the spin-labels in molecules, the only limitation in imaging single spins in molecules with the NV center, is the spatial resolution. Every electron spin in resonance with the measurement scheme contributes to the signal and thereby reduces the probability of detecting single spins. The aim of this work is to spatially restrict the number of resonant electron spins by using a strong magnetic field gradient. Since strong off-axis magnetic fields disturb the optical readout of the NV center spin state, we try to fabricate magnetic tips with low total magnetic field strength but with a gradient in the range of 10G/nm. Commercially available magnets, like AFM tips, do not generate such fields. This work is split up into three steps, first the micromagnetic simulation of the required geometry, secondly the fabrication of high gradient magnetic on tips and finally the integration of such tips into an AFM setup for measurements with an NV center.

MA 67.23 Fri 9:30 P2-OG3

How to detect magnetically labeled cells using magnetoelectric sensors — •Ron-Marco Friedrich[1], Jan-Martin Wagner[1], Sebastian Zabel[1], Christine Selhuber-Unkel[2], and Franz Faupel[1] — [1]CAU Kiel, Institute for Materials Science, Chair for Multicomponent Materials, Kaiserstr. 2, 24143 Kiel, Germany — [2]CAU Kiel, Institute for Materials Science - Biocompatible Nanomaterials, Kaiserstr. 2, 24143 Kiel, Germany

The detection of magnetically labeled cells has been of great interest in recent years and holds significant possibilities in the field of biomedical sciences for the nondestructive and non-invasive imaging of cells in 3D scaffolds. Here, a new detection method using magnetoelectric (ME) sensors is introduced where, similar to magnetic particle imaging (MPI), the nonlinear magnetization behavior of magnetic particle ensembles is used to detect higher harmonic excitations. These ME sensors, consisting of magnetostrictive and piezoelectric layers on a cantilever, show very high sensitivity anisotropy and sharp mechanical resonance, which leads to selective signal acquisition with regard to spatial orientation and excitation frequency. Using such inherent features of the sensor and the nonlinear magnetization behavior of nanoparticles, the objective is to detect and locate cells by scanning over the sample with the detector while applying a homogeneous alternating magnetic field. To achieve this objective, we formulate the restrictions and necessities of the detection system and analyze them with regard to measureable fields, particle densities, external magnetic fields, excitation frequencies and sensor orientations.

MA 67.24 Fri 9:30 P2-OG3

Nanoscale temperature sensing for a new generation of hard disk recording heads — •Sven Bodenstedt[1], Ingmar Jakobi[1], Fadi El Hallak[2], Philipp Neumann[1], and Jörg Wrachtrup[1] — [1]3. Physikalisches Institut, Universität Stuttgart — [2]Seagate Technology

State of the art hard disk recording heads use magnetic fields to encode data as magnetization on small sectors on a recording medium. A new generation of recording heads, called Heat Assisted Magnetic Recording (HAMR) [1], employs an additional nanoscopic heat spot to reduce the coercivity of a single recording bit on the recording medium. Although HAMR heads are not yet available in commercial drives this technology may increase storage capacities by orders of magnitude.

The development of the device hinges on suitable sensors for the nanoscale characterization of the produced heat. Nitrogen-vacancy (NV) defect centers in diamond are the ideal candidate for this task. In addition to being efficient magnetometers that can be used to survey the magnetic field of recording heads [2] they are also sensitive to temperature changes [3, 4]. Here we present our work to bring a NV nanoscale thermometer to the hard disk industry.

[1] M. Krayder et al., Proceedings of the IEEE, 2008
[2] I. Jakobi et al., Nature Nanotechnology, 2016
[3] P. Neumann et al., Nano Letters, 2013
[4] A. Laraoui et al., Nature Communications, 2015

MA 67.25 Fri 9:30 P2-OG3

Scanning Tunneling Microscopy in the Field Emission regime revisited — •Gabriele Bertolini, Lorenzo G. De Pietro, Oguzhan Gürlü, Urs Ramsperger, and Danilo Pescia — ETH Zurich, Zurich, Switzerland

In a Scanning Tunnelig Microscope retracting the tip from the sample by 5 to 100 nm and applying a suitable junction bias (-10 to -100 V tip bias) between them bring the tip-sample junction out of the tunnelling regime and the tip becomes a source of electrons due to field emission. In this regime the electrons arriving from the tip to the sample cause the generation of secondary electrons on the sample surface, which can escape from the tip-sample junction. Such electrons may be collected by several means and analysed. This technique is called as Field Emission Scanning Probe Microscopy. The strong dependence of the physical properties of the secondary electrons on the nature of the sample surface makes complementary information accessible. Besides the emitted and absorbed current maps and the z-piezo displacement images of the surface, chemical and magnetic contrast with nanometer scale resolution can be achieved on the same region that was scanned previously in the STM mode. We are currently aiming at detecting the spin polarization of the secondary electrons, for the purpose of magnetic imaging. In this presentation structural and electronic properties obtained on several pure-metallic and compound surfaces with previously not reported lateral resolution will be discussed.

MA 67.26 Fri 9:30 P2-OG3

Spectral properties of the longitudinal spin Seebeck effect — •Timo Noack, Thomas Langner, Frank Heussner, Viktor Lauer, Oleksandr Serha, Burkard Hillebrands, and Vitaliy Vasyuchka — Fachbereich Physik der TU Kaiserslautern und Landesforschungszentrum OPTIMAS, 67663 Kaiserslautern, Germany

The transitional dynamics of the longitudinal spin Seebeck effect (LSSE) was investigated in YIG/Pt bilayers. Two experimental approaches were used to measure LSSE in a wide range of YIG thicknesses. Firstly, a pulsed microwave signal was applied to the structure and the subsequent thermal gradient gives rise to a LSSE-voltage pulse, which was measured by an oscilloscope. Over the thickness range from 270 nm to 53 μm we observed an increase of the rise-time by a factor of 42. Secondly, the heating microwave signal was modulated by a low-frequency signal and the LSSE-voltage was measured for different modulation frequencies. The cut-off frequency was extracted from the LSSE transfer function. It shows an inverse proportional dependence to the magnetic layer thickness. Both experiments can be understood by considering the transfer properties of the magnons in their diffusive process. Financial support by the Deutsche Forschungsgemeinschaft within SPP 1538 "Spin Caloric Transport" is gratefully acknowledged.

MA 67.27 Fri 9:30 P2-OG3

Towards an understanding of the basic mechanism of hysteresis at a first-order magneto-structural transition — •F. Scheibel[1], Ö. Çakir[2], T. Gottschall[3], M. Ghorbani Zavareh[4,5], C. Salazar Mejia[4], Y. Skourski[4], F. Cugini[6], A. Tekgül[7], O. Gutfleisch[3], J. Wosnitza[4], M. Solzi[6], M. Farle[1], and M. Acet[1] — [1]Faculty of Physics and CENIDE, University Duisburg-Essen, 47057 Duisburg, Germany — [2]Physics Department, Yildiz Technical University, 34349 Istanbul, Turkey — [3]Materialwissenschaft FG Funktionale Materialien , Technische Universität Darmstadt, 64289 Darmstadt, Germany — [4]Hochfeld-Magnetlabor Dresden, Helmholtz-Zentrum Dresden-Rossendorf, Germany — [5]Chemical Physics of Solids, Max-Planck-Institute, 01187 Dresden, Germany — [6]Physics Department and CNISM, University of Parma, 43121 Parma, Italy — [7]Physics Department, Akdeniz University, 07058 Antalya, Turkey

The reversibility of the adiabatic temperature change ΔT in materials with a first-order magneto-structural transition (FOMST) is limited by the thermal hysteresis of the transition, making it a critical factor for refrigeration applications. Adiabatic magnetization and ΔT studies with different field-change rates up to 700 T/s are performed to understand the dynamics of the FOMST for antiperovskites, Heuslers, and transition metal pnictides. In particular, the effect of long range ferromagnetic ordering on the hysteresis is investigated. Work supported by the Deutsche Forschungsgemeinschaft (SPP 1599).

MA 67.28 Fri 9:30 P2-OG3

First Principles Calculations towards the Magnetic Phase Diagram of Quaternary Heusler Alloys — •Marianne Schröter, Anna Grünebohm, and Peter Entel — Universität Duisburg-Essen, Germany

Recently magnetic Heusler alloys have become of interest because of their giant inverse magnetocaloric effect and its desirous relevance for magnetic refrigeration[1]. Adding elements to the ternary Heusler alloys can tune the effect[2].

We investigate the influence of Cr and Co as quarternary elements on the magnetic phase diagram of NiMnGa. On the basis of DFT supercell calculations we look at the energy landscapes of theses alloys for different magnetic phases. KKR-CPA calculations together with subsequential Monte Carlo simulations highlight the degree of magnetic frustration in these systems. In the case of Cr for Ni substitution we see that energetically favoured are those states where the magnetic moments of Mn moments are ferromagnetically aligned. On the other hand the total magnetization is reduced by the antiferromagnetic alignment of Cr.

[1] K. A. Gschneidner et al., Rep. Prog. Phys. 68, 1479 (2005)
[2] V. V. Sokolovskiy et al., Phys. Rev. B 91, 220409(R) (2015)

MA 67.29 Fri 9:30 P2-OG3

Direct measurements of ΔT in magnetocaloric and electrocaloric samples utilizing modulated fields at variable frequencies — •Jago Döntgen[1], Jörg Rudolph[1], Steffen Salomon[2], Alfred Ludwig[2], Tino Gottschall[3], Oliver Gutfleisch[3], Anja Waske[4], Sylvia Gebhardt[5], and Daniel Hägele[1] — [1]AG Spektroskopie d. kondensierten Materie, Ruhr-Universität Bochum — [2]Werkstoffe der Mikrotechnik, Ruhr-Universität Bochum — [3]Funktionale Materialien, Technische Universität Darmstadt — [4]Institut für komplexe Materialien, IFW Dresden — [5]Multifunktionale Werkstoffe und Bauteile, Fraunhofer IKTS Dresden

We present magneto- and electrocaloric data taken by our newly developed non-contact technique for direct measurements of the adiabatic temperature change in modulated fields. High field frequencies allow for magnetocaloric measurements on low volume samples, as demonstrated on a gadolinium film as thin as 1.4 μm. The dynamic behaviour of hydrogenated La-Fe-Si and gadolinium is investigated by applying modulated magnetic fields at varying frequencies up to 1.2 kHz. The experimental setup is further used to measure the electrocaloric effect in the relaxor dielectric PMN-PT, which exhibits a pronounced ageing behaviour both in its dielectric and electrocaloric properties.

MA 67.30 Fri 9:30 P2-OG3

Structural characterization of multicaloric, epitaxial Ni-Mn-Ga-Co thin films on piezoelectric substrates — •Stefan Schwabe[1,2], Benjamin Schleicher[1], Robert Niemann[1], Anja Waske[1], Ruben Hühne[1], Kornelius Nielsch[1,2], and Sebastian Fähler[1] — [1]IFW Dresden, P.O. Box 270116, D-01171 Dresden, Germany. — [2]TU Dresden, Institute of Materials Science, D-01069 Dresden, Germany.

Heusler alloys of the type Ni-Mn-Co-X (with X = Ga, In, Sb, Sn) are a promising material class for solid state cooling applications. They undergo a phase transition between the austenite at high and the martensite at lower temperatures accompanied by a reduction of crystal symmetry and the occurrence of an inverse magnetocaloric effect. This transformation can be influenced by the temperature, an applied magnetic field, but also mechanical stress. An epitaxial growth of thin films offers a well-defined orientation relation making it possible to model the structure of the twinned, low symmetry phase. Therefore, thin films were prepared on piezoelectric substrates and mechanically stressed by the application of an electric field. We present an investigation of Ni-Mn-Ga-Co thin films on piezoelectric PMN-PT substrates, which were grown epitaxially via sputter deposition. The structure of the martensite was probed with different X-ray diffraction methods, including 2D synchrotron XRD-measurements. The diffraction patterns are compared to calculated ones using the phenomenological martensite theory to examine the martensitic structure and influence of the stress. This work is supported by DFG through SPP 1599, www.FerroicCooling.de.