MA 20: POSTER Ib

Magnetisierungsdynamik, Spintransport, Spintronics

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

MA 20.1 Tue 9:30 Poster A

Annealing influence on the spin-dynamic properties of CoFeB thin films — •Tobias Fischer[1], Thomas Meyer[1], Thomas Brächer[1], Björn Heinz[1], Andrés Conca[1], Evangelos Papaioannou[1], Stefan Klingler[1], Jochen Greser[1], Thomas Sebastian[1,2], Britta Leven[1], Jörg Lösch[3], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Current affiliation: Helmholtz-Zentrum Dresden-Rossendorf, Bautzner Landstr. 400, 01328 Dresden — [3]Institut für Oberflächen- und Schichtanalytik GmbH (IFOS) and Landesforschungszentrum OPTIMAS, Trippstadter Str. 120, 67663 Kaiserslautern, Germany

Materials and material systems with ultra-low Gilbert damping parameters are a crucial requirement for the realization of spin-wave logic devices. For that, CoFeB is a promising candidate due to its intrinsically low damping. Our aim is to investigate the suitability of an annealing step to further decrease the damping in CoFeB-based systems. Ferromagnetic resonance measurements as well as the magneto-optical Kerr effect reveal the dependence of the Gilbert damping parameter, the exchange constant, the saturation magnetization, and the coercive field on the annealing temperature. The correlation of these parameters with the crystalline properties is determined using X-ray diffractometry. Furthermore, we present Brillouin light scattering spectroscopy measurements of spin waves in waveguides showing the influence of annealing on the spin-dynamic properties.

MA 20.2 Tue 9:30 Poster A

***Ab initio* investigation of light-induced relativistic spin-flip effects in femtosecond magneto-optics** — •Ritwik Mondal[1], Marco Berritta[1], Karel Carva[1,2], and Peter M. Oppeneer[1] — [1]Uppsala University, Uppsala, Sweden — [2]Charles University, Prague, Czech Republic

Excitation of a metallic ferromagnet such as Ni with an intensive fs laser pulse causes an ultrafast demagnetization within ∼300 fs. It was proposed that this could be due to relativistic light-induced processes: direct light-induced spin-flip[1] or coherent relativistic electrodynamic processes[2] (see also[3]). We perform an *ab initio* study of the influence of these relativistic effects on the magneto-optical response of Ni. We compute the influence of relativistic spin-flip transitions and develop response theory for ultra-relativistic terms due to the electromagnetic field. Our *ab initio* calculations of relativistic spin-flip optical excitations predict that these give only a very small contribution to the laser-induced demagnetization. Support from the EU (grant No. 281043, FemtoSpin) is acknowledged.
[1]G.P. Zhang *et al.*, Nature Phys. **5**, 499 (2009). [2]J.-Y. Bigot *et al.*, Nature Phys. **5**, 515 (2009). [3] K. Carva *et al.*, Nature Phys. **7**, 665 (2011).

MA 20.3 Tue 9:30 Poster A

Determination of the Exchange Stiffness Constant in Ultrathin Magnetic Films by Ferromagnetic Resonance — •Manuel Langer[1,2], Kai Wagner[1], Thomas Sebastian[1], Helmut Schultheiss[1], Kilian Lenz[1], Jürgen Lindner[1], and Jürgen Fassbender[1,2] — [1]Institute of Ion Beam Physics and Materials Research, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden — [2]Technical University Dresden, 01069 Dresden

In ultrathin magnetic films of 10 — 20 nm thickness, it is hardly possible to determine the exchange constant A using conventional techniques, such as Brillouin light scattering. In this work, a method is presented allowing for analytical determination of the exchange constant A in ultrathin magnetic films.
Periodical surface modulations are introduced by electron beam lithography with subsequent sub-nanometer etching. The periodical stray field induces two-magnon scattering leading to a coupling of the uniform excitation with higher in-plane spin waves.
An analytical model is presented, that can be used to precisely calculate the exchange constant A under usage of the measured ferromagnetic resonance spectra (frequency versus field dependence).
This work is supported by DFG grant LE2443/5-1.

MA 20.4 Tue 9:30 Poster A

Phase-to-amplitude conversion by parallel parametric amplification of propagating spin waves in microstructured $Ni_{81}Fe_{19}$ waveguides — Thomas Brächer, •Frank Heussner, Philipp Pirro, Thomas Meyer, Alexander Serga, and Burkard Hillebrands — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, D-67663 Kaiserslautern, Germany

We report on controlling the intensity of a propagating spin wave after passing through a localized amplification area in a transversally magnetized $Ni_{81}Fe_{19}$ (Py) waveguide by phase matching. A microwave current inside a microstrip transmission line with a narrowing underneath the Py waveguide creates a locally enhanced dynamic magnetic field parallel to the static magnetization. By applying an alternating magnetic field of frequency $2f_{SW}$, parametric interactions can lead to an amplification of a coherently excited spin wave of frequency f_{SW}. This effect is known as parallel parametric amplification (PPA).

The amplification is phase-sensitive, i.e., it depends on the phase difference $\Delta\Phi$ between the phase Φ_{2f} of the magnetic pumping field and the phase Φ_f of the propagating spin wave. By utilizing Brillouin light scattering (BLS) microscopy, we demonstrate that the level of the transmitted spin-wave intensity behind the amplification area can be continuously tuned by adjusting the phase difference $\Delta\Phi$. The result of this work commends itself for applications in information processing as it allows for the realization of a phase-to-amplitude conversion based on phase-sensitive parallel parametric amplification.

MA 20.5 Tue 9:30 Poster A

Ultrafast Magnetostriction of Antiferromagnetic Holmium studied by Femtosecond X-ray Diffraction — •Jan-Etienne Pudell[1], Alexander von Reppert[1], Flavio Zamponi[1], Matthias Rössle[1], Daniel Schick[2], and Matias Bargheer[1,2] — [1]Institut für Physik und Astronomie, Universität Potsdam, Karl-Liebknecht-Str. 24-25, 14476 Potsdam, Germany — [2]Helmholtz-Zentrum Berlin, Wilhelm-Conrad-Röntgen Campus, BESSY II, Albert-Einstein-Str. 15, 12489 Berlin, Germany

We present time-resolved X-ray diffraction on a Holmium thin film after femtosecond laser excitation. The lattice shows rich spatio-temporal dynamics, where the contraction and expansion are driven by the excitation of electrons, magnons and phonons.

The indirect exchange interaction (RKKY) in the 80 nm Holmium film leads to an incommensurate helical antiferromagnetic (AFM) spin structure below the Néel temperature of approx. 131 K. The strong magnetostriction in Holmium results in an decrease of the lattice constant with temperature. The sub-pico to nanosecond lattice dynamics after photoexcitation are studied by ultrafast X-ray diffraction (UXRD) using a laser-driven Plasma X-ray Source (PXS). The sample is excited with 800 nm femtosecond laser pulse of different fluences starting at various temperatures below and above the Néel temperature of Holmium. The phonon driven lattice expansion takes place within 15 ps and is sound velocity limited. Below the Néel temperature, the heating of the magnetic system induces an ultrafast magnetostriction, which leads to a contraction within 25 ps.

MA 20.6 Tue 9:30 Poster A

Threshold photoemission magnetic circular dichroism as a tool for high-resolution imaging of magnetization structures — •Maximilian Staab[1,2], Hans Joachim Elmers[1], Mathias Kläui[1,2], and Gerd Schönhense[1] — [1]Johannes Gutenberg-Universität Mainz — [2]MAINZ Graduate School of Excellence

Time-resolved imaging of magnetic structures and their dynamics is the domain of Kerr microscopy (being limited in resolution) and Synchrotron-based XMCD PEEM. On the quest to faster imaging we pursue the excitation with a laboratory-based Ti-sapphire laser exploiting magnetic circular dichroism in threshold photoemission (TPMCD). Our experiment uses a photoemission electron microscope (PEEM) and photoelectron excitation by circularly polarized light of 1.6 eV (fundamental of the laser) and 3.2 eV (second harmonic). The TPMCD asymmetries are based on different probabilities of transitions between spin-dependent electronic bands in the near photoemission threshold region. The TPMCD exists in one-photon-photoemission (1PPE) [1] and also in two-photon-photoemission (2PPE) [2]. In order to do spatially resolved imaging of a magnetic domain pattern we fabricated thin magnetic films consisting of a few monolayers of Co on top of a Pt(111) single crystal and performed PEEM measurements. Using a femtosecond laser as photon source will allow pump-probe experiments to add high time resolution to the PEEM setup. Project funded by DFG EL172/15. [1] K. Hild et al., Phys. Rev. B Vol. 80(22), pp. 224426, (2009) [2] K. Hild et al., Phys. Rev. Lett. 102, 057207, (2009)

MA 20.7 Tue 9:30 Poster A

Femtosecond demagnetization of Nickel/Gold: rotation vs ellipticity — •Moritz Barkowski, Oliver Schmitt, Jurij Urbancic, Steffen Eich, Jingyi Mao, Sakshath Sadashivaiah, Daniel Steil, Mirko Cinchetti, Stefan Mathias, and Martin Aeschlimann — Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

Using femtosecond time-resolved MOKE to study ultrafast demagnetization is today a standard experimental approach. However, there is still an ongoing debate on the so called optical artifacts in the signal, and when and how true magnetization dynamics are extracted. In our measurements of ultrafast demagnetization of Ni/Au we have the peculiar situation that the MOKE rotation & ellipticity signals differ by demagnetization constants of a factor of two. In order to distinguish demagnetization from non-magnetic effects, we study this system with different fs-techniques and for varying material compositions.

MA 20.8 Tue 9:30 Poster A

Sign change of MOKE-signals in engineered AOS materials — •Ute Bierbrauer[1], Sabine Alebrand[1], Michel Hehn[2], Charles-Henri Lambert[2], Daniel Steil[1], Oliver Schmitt[1], Eric Fullerton[3], Stéphane Mangin[2], Mirko Cinchetti[1], Stefan Mathias[1], and Martin Aeschlimann[1] — [1]TU Kaiserslautern, Deutschland — [2]IJL Nancy, Frankreich — [3]CMR San Diego, USA

Since the discovery of a transient ferromagnetic-like state in amorphous rare-earth transition-metal alloy films [1] a connection between this ultrafast magnetization process and helicity-dependent all-optical switching (AOS) is assumed.

Here we demonstrate that a sign change of the magnetization within a fs demagnetization experiment [2] can also be observed in the recently discovered [3,4] more complex AOS systems, including ferrimagnetic and ferromagnetic multilayer structures. We show our recent results in this field with regard to the ultrafast magnetization dynamics of these materials, particularly with a closer view on the magnetization reversal occurring on the femtosecond timescale. The presented results link the appearance of a transient negative MOKE signal as a required property of AOS materials.

[1] Radu et al. Nat. 472 (7342), 205-8 (2011)
[2] Alebrand et al., PRB 89, 144404 (2014)
[3] Mangin et al.Nat. Mat. 13, 286-292 (2014)
[4] Lambert et al. Science 325 (6202), 1337-1340 (2014)

MA 20.9 Tue 9:30 Poster A

Band Structure calculation of thin film YIG based magnetic crystal — •Tobias Stückler, Ping Che, Sa Tu, and Haiming Yu — Spintronics Interdisciplinary Center, Department of Electronic and Information Engineering, Beihang University Beijing, 100191, China

Magnonic crystals (MCs) are a new class of magnetic nanostructures. They become the key to provide the possibility of studying frequency bands and band gaps of magnetic materials. MCs can be used to develop new applications, like spin filters. We study spin wave propagation in MCs based on magnetic insulator thin film YIG and report simulation of band information and forbidden band gap for frequencies tuned by the crystal lattice and the materials.

MA 20.10 Tue 9:30 Poster A

Transport effects and ultrafast magnetization dynamics in laser-excited metals — •Linda Thesing[1], Benedikt Y. Mueller[2], and Baerbel Rethfeld[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Max-Planck-Institut fuer Intelligente Systeme, Stuttgart, Germany

The equilibration of intense thermodynamic variables has been found to dominate ultrafast magnetization dynamics [1]. In itinerant ferromagnets, these variables may be considered separately for spin-up and spin-down electrons. The temporal evolution of electron and phonon temperatures as well as chemical potentials can be described with help of the μT model [2], which is based on a phenomenological two temperature description. The μT model has identified the minimum of magnetization as a transient equilibrium state. It also explains the experimentally observed slowing down of the magnetization dynamics by a critical region in the magnetic phase diagram [2]. Considering spatial effects, the excitation of a ferromagnetic sample with an ultrashort laser pulse does not only result in gradients of electron temperatures but also of the chemical potential of the electrons. The μT model allows to trace the equilibration of such gradients, and additionally accounts for transport effects such as Seebeck or Peltier effect. Therefore, it opens the possibility to describe ultrafast magnetization dynamics driven by different chemical potentials [1] *and* transport effects.

[1] B. Y. Mueller et al., PRL 111, 167204 (2013)
[2] B. Y. Mueller and B. Rethfeld, PRB 90, 144420 (2014)

MA 20.11 Tue 9:30 Poster A

Altering the spin wave frequency spectra in vortex structures by simultaneous excitations of the vortex gyromode — •Markus Härtinger[1], Hans G. Bauer[1], Hermann Stoll[2], and Christian Back[1] — [1]Department of Physics, University of Regensburg, 93040 Regensburg, Germany — [2]Max Planck Institute for Intelligent Systems, 70569 Stuttgart, Germany

In nano-sized ferromagnetic disks recent experiments and micromagnetic simulations of simultaneous excitations of both, the gyromode and spin wave modes, result in a significant reduction of the vortex core (VC) switching threshold[1]. By micromagnetic simulations H.G. Bauer et al.[2] revealed that two frequency excitation below the switching-threshold results in a frequency splitting of the lowest spin wave mode.

Here we report on an experimental verification by VNA-FMR measurements of the frequency spectrum of the azimuthal spin waves when the sub-GHz gyromode is resonantly excited simultaneously in $Ni_{80}Fe_{20}$ disks, 1.6 μm in diameter. Without excitation of the gyromode, the first two magnetostatic spin wave modes ($n = 1, m = \pm 1$) are observed at about 5 GHz and 6.5 GHz. After additional simultaneous excitation at the gyromode eigenfrequency (about 250 MHz) we observe a decrease and broadening of the lower frequency spin wave absorption peak for the increased gyro-excitation amplitude as predicted by micromagnetic simulations[2].

[1] M. Sproll et al. Appl. Phys. Lett. **104**, 012409 (2014)
[2] H.G. Bauer et al. Phys. Rev. Lett. **112**, 077201 (2014)

MA 20.12 Tue 9:30 Poster A

Ultrafast Magnetization Dynamics of Gd and Tb studied by XMCD — •Kamil Bobowski[1], Robert Carley[1,2], Björn Frietsch[1], Markus Gleich[1], Martin Teichmann[1,2], Christoph Trabant[1], Marko Wietstruk[1], and Martin Weinelt[1] — [1]Fachbereich Physik der Freien Universität Berlin, Arnimallee 14, 14195 Berlin, Germany — [2]European XFEL GmbH, Albert-Einstein-Ring 19, 22761 Hamburg, Germany

Our recent time- and angle-resolved photoemission study [1] questions the ultrafast Gd 4f spin dynamics measured previously on sandwiched polycrystalline Gd films using X-ray magnetic circular dichroism (XMCD) in transmission [2]. To answer this question, we performed pump-probe experiments on single-crystalline Gd combining optical excitation and femtosecond XMCD in reflection. In a first preparatory beamtime, we showed the feasibility of this experiment by measuring simultaneously the reflection and absorption signal while varying the temperature from 100 K to above the Curie temperature. For comparative measurements, a Tb sample was investigated in the same way. Furthermore, we present preliminary results of the magnetization dynamics of the Gd 4f spins which were measured at the FEMTOSPEX beamline at BESSY II.

[1] B. Frietsch *et. al.*, submitted.
[2] M. Wietstruk *et. al.*, *Phys. Rev. Lett. 106* **25**, 127401 (2011).

MA 20.13 Tue 9:30 Poster A

Laser induced meta-stable magnetic structures probed by Lorentz microscopy — •Marcel Möller[1], Jan Gregor Gratzmann[1], Armin Feist[1], Nara Rubiano da Silva[1], Vladyslav Zbarsky[2], Markus Münzenberg[3], Claus Ropers[1], and Sascha Schäfer[1] — [1]IV. Physical Institute, University of Göttingen, 37077 Göttingen, Germany — [2]I. Physical Institute, University of Göttingen, 37077 Göttingen, Germany — [3]Institut fur Physik, Greifswald University, 17489 Greifswald, Germany

Ultrashort laser excitation allows for an all-optical control of magnetic structures [1]. On the micrometer-scale, laser-induced magnetic changes can be imaged using, for example, Faraday microscopy.

Here, we employ in-situ Lorentz microscopy to study meta-stable magnetic structures generated by femtosecond optical pulse pairs with variable polarization states. As a first example, we investigate homogenous iron thin-films and observe an optically triggered switching of ripple domains at low excitation fluence. For laser pulse energies above a well-defined threshold, new meta-stable magnetic structures are formed, consisting of a dense network of vortices and antivortices with a charateristic correlation length of about 500 nm. Furthermore, we present first results using Lorentz microscopy in an ultrafast transmission electron microscope (UTEM) utilizing sub-picosecond electron pulse probing.

[1] Mangin, S., et al. "Engineered materials for all-optical helicity-dependent magnetic switching." Nature materials 13.3 (2014): 286-292.

MA 20.14 Tue 9:30 Poster A

Spin pumping by magnetization precession in a wide frequency range — •Viktor Lauer, Thomas Brächer, Burkard Hillebrands, and Andrii Chumak — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaisterslautern, Germany

Spin pumping refers to the spin-current generation in a normal metal film caused by the magnetization precession in an attached magnetic film. Via the inverse spin Hall effect (ISHE) this spin current is transformed into a conventional charge current.

Various parameters influence the spin-pumping induced ISHE voltage and require experimental analysis in order to understand the physical principles behind. In our study we address the dependence of spin pumping on the frequency of the magnetization precession, for frequencies 1-45 GHz. Our spin-pumping experiments were performed on a YIG(100nm)|Pt(10nm) bi-layer system. Theoretical predictions show that the generated voltage should decrease monotonically with increase in frequency. However, we observe a more complex ISHE voltage dependence on frequency, that exhibits a pronounced maximum at 11 GHz. The behaviour above 11 GHz qualitatively agrees with theoretical predictions. The deviation from theory below 11 GHz may be due to the frequency dependent excitation efficiency because of the precession ellipticity, as well as due to the change of pinning conditions by the external magnetic field.

MA 20.15 Tue 9:30 Poster A

Anisotropy of anomalous Hall effects in YIG|Pt hybrids — Sibylle Meyer[1,2], •Richard Schlitz[1,2], Stephan Geprägs[1], Matthias Opel[1], Hans Huebl[1,3], Rudolf Gross[1,2,3], and Sebastian T. B. Goennenwein[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich, 80799 München, Germany

The generation, manipulation and detection of pure spin currents are fascinating challenges in the field of spintronics. Recently, the spin Hall magnetoresistance (SMR) effect based on the interplay of spin and charge currents was reported [1]. The SMR allows to determine the imaginary part of the spin mixing interface conductance from measurements of anomalous Hall-type effects (spin Hall anomalous Hall effect, SHAHE [2]). Here, we present the analysis of ordinary and anomalous Hall signals observed in magnetotransport measurements in yttrium iron garnet|platinum (YIG|Pt) bilayers. We discuss the dependence on film thickness and temperature of the AHE voltage signals in terms of the SHAHE. Whereas the usual AHE voltage signal observed in metallic ferromagnets depends linearly on the magnetization component $M_\perp$ perpendicular to the film, we observe a more complex AHE-type response in our YIG|Pt samples. In particular, we observe higher order terms $\propto M_\perp^n$ at low temperatures.
This work is supported by the DFG via SPP 1538 (GO 944/4).

[1] H. Nakayama *et al.*, Phys. Rev. Lett. **110**, 206601 (2013).
[2] Y.-T. Chen *et al.*, Phys. Rev. B **87**, 144411 (2013).

MA 20.16 Tue 9:30 Poster A

Spin current experiments in Ga-doped Yttrium Iron Garnets — •Michaela Lammel[1,2], Stephan Geprägs[1], Matthias Opel[1], Sebastian T.B. Goennenwein[1,2,3], and Rudolf Gross[1,2,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, Technische Universität München, 85748 Garching, Germany — [3]Nanosystems Initiative Munich, 80799 München, Germany

Garnets, in particular yttrium iron garnet (YIG), are widely used for experiments with spin currents. A particularly interesting aspect hereby are the different sublattice magnetizations. To clarify the specific role of the magnetic moments of the two iron sub-lattices of YIG, we investigate gallium substituted YIG ($Y_3Fe_{5-x}Ga_xO_{12}$, Ga:YIG) samples. Varying the Ga concentration, the compensation temperature T_{comp}, at which the magnetic moments on the two iron sublattices cancel each other, can be tuned. We fabricated Ga:YIG thin films on $Y_3Al_5O_{12}$ substrates by pulsed laser deposition (PLD). The crystalline quality was determined by high-resolution X-ray diffractometry. No parasitic phases could be detected and a high crystalline quality of the epitaxial films could be inferred from the small FWHM of the measured rocking curves. Using SQUID magnetometry, the temperature dependence of the magnetization was studied at different applied magnetic fields. Our results show that the compensation temperature T_{comp} depends crucially on the deposition parameters. — This work is supported by the DFG via SPP 1538.

MA 20.17 Tue 9:30 Poster A

Temperature Dependence of the Spin Seebeck Effect in Iron Garnets — •Francesco Della Coletta[1,2], Andreas Kehlberger[3], Tomek Schulz[3], Christian Mix[3], Sibylle Meyer[1,2], Matthias Althammer[1], Hans Huebl[1,4], Gerhard Jakob[3], Stephan Geprägs[1], Rudolf Gross[1,2,4], Sebastian T. B. Goennenwein[1,4], and Mathias Kläui[3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik-Department, TU München, 85748 Garching, Germany — [3]Institute of Physics, University of Mainz, 55099 Mainz, Germany — [4]Nanosystems Initiative Munich, 80799 München, Germany

In spin Seebeck effect (SSE) experiments, pure spin currents are driven across a magnetic insulator/normal metal interface by thermal gradients, and detected via the inverse spin Hall effect. Upon using ferrimagnetic insulators, e.g. iron garnets $A_3Fe_5O_{12}$ (AIG), comprising different magnetic sublattices in SSE experiments, the question arises whether the spin current properties simply are connected to the net magnetization, or whether the different magnetic sublattices contribute in a more subtle way. We have measured the temperature dependence of the SSE signal in AIG/Pt bilayers with $A = \mathrm{Gd}, \mathrm{Dy}$, and find two consecutive sign changes. The first sign change occurs near the magnetic compensation temperature, where the net magnetization of the three sub-lattices is zero. The second sign change shows that the SSE signal results from a complex interplay of the three magnetic sublattices involved. — This work is supported by the DFG via SPP 1538.

MA 20.18 Tue 9:30 Poster A

Optical Detection of Electrical Spin Injection into a High Mobility 2DEG System — •Martin Buchner, Martin Oltscher, Mariusz Ciorga, Josef Loher, Dieter Schuh, Dominique Bougeard, Dieter Weiss, and Christian Back — Department of Physics, Regensburg University, 93053 Regensburg, Germany

In 1990 Datta and Das proposed a novel transistor concept, which utilizes the electron's spin as a new degree of freedom [1]. The current modulation arises from spin precession, which originates from the Bychkow-Rashba-term of spin-orbit-interaction. One key ingredient for the experimental realization of the device is spin injection into a two-dimensional electron gas (2DEG), which turned out to be a challenging task.

In this study, we demonstrate spin injection into a high mobility 2DEG, investigated by means of scanning Kerr microscopy at the cleaved edge of the sample. In detail, we investigate samples with the 2DEG confined at an (Al,Ga)As/GaAs interface; ferromagnetic (Ga,Mn)As contacts are used as spin aligners. The spatial distribution of the spins is probed by a diode laser directly underneath the injecting contact. Hanle depolarization gives a measure for the spin lifetimes.

[1] S. Datta, B. Das, Appl. Phys. Lett. 56, 665 (1990).

MA 20.19 Tue 9:30 Poster A

Magnetotransport of arrays of hybrid magnetic nanowires grown in porous alumina templates — •Sergej Andreev, Julian Braun, and Torsten Pietsch — Department of Physics, University of Konstanz, Universitätsstraße 10, 78464 Konstanz, Germany

Highly ordered hexagonal arrays of metallic and semiconducting nanowires recently attracted considerable interest due to potential applications in energy storage and -conversion as well as catalysis and communication technologies. Porous alumina templates have been widely used to fabricate such nanowires with diameters in the range of 50 nm to hundreds of nanometers. Here, we investigate novel types of hetero-nanowires fabricated via deposition of different metals into porous alumina templates. The nanowires with diameters down to 20 nm are prepared via co-electrodeposition of different magnetic metals. We show that micrometer sized arrays of nanowires can be integrated into lithographically designed circuits and we investigate the (magneto)-transport properties of magnetic hetero-nanowires at low temperatures.

MA 20.20 Tue 9:30 Poster A

Separation of the longitudinal spin Seebeck effect and additional magnetothermopower effects in Pt/YIG bilayers — •Panagiota Bougiatioti, Daniel Meier, Christoph Klewe, Gerhard Götz, Günter Reiss, and Timo Kuschel — CSMD, Physics Department, Bielefeld University, Germany

In the emerging fields of spintronics and spin caloritronics recently discovered phenomena such as the spin Hall effect, the spin Hall magnetoresistance and the longitudinal spin Seebeck effect (LSSE), enable the generation, manipulation and detection of spin polarized currents. Further, the spin Nernst effect and the spin Nernst magnetothermopower (SMTP) are expected to be reported soon. Pt has been employed quite often for generating and detecting a pure spin current, if adjacent to a magnetic insulator, although the question of proximity effects has to be taken into account [1]. In this project we investigate the separation of the LSSE and additional magnetothermopower effects in Pt/YIG bilayers. Therefore, a temperature gradient was generated by heating the electric contacts [2] or by applying a charge current along the Pt stripe. In magnetic field rotation measurements we detect several voltage contributions which can be attributed to the LSSE and to additional magnetothermopower effects. We separate the contributions and discuss the probable amount of classical anisotropic magnetothermopower effects and of the new SMTP.

[1] T. Kuschel et al., submitted (2014), arxiv: 1411.0113
[2] D. Meier et al., Phys. Rev. B 88, 184425 (2013)

MA 20.21 Tue 9:30 Poster A

Rotation of in-plane thermal gradients in spin caloric measurements — •Oliver Reimer, Michel Bovender, Daniel Meier, Lars Helmich, Andreas Hütten, Jan-Michael Schmalhorst, Günter Reiss, and Timo Kuschel — CSMD, Physics Department, Bielefeld University

In spin caloric measurements ∇T acts as a driving force for spin currents. A ferromagnet exposed to ∇T in an external magnetic field generates a spin current parallel to ∇T (longitudinal spin Seebeck effect [1]) which can be detected in materials with high spin orbit coupling (e.g. Pt) by the inverse spin Hall effect. In paramagnets the spin Nernst effect is expected to cause a transverse spin current which can induce a spin torque transfer at the interface to a magnetic material. Thus, ∇T can be used in combination with an external magnetic field to manipulate the electric resistance in the paramagnet (spin Nernst magnetothermopower) similar to the current driven spin Hall magnetoresistance [2,3]. Since all these spin caloric effects are characterized by using a spatial fixed ∇T varying only the base temperature and the difference of the temperatures, we introduce a new setup which allows the rotation of ∇T. First experiments on different substrates controlled by an infrared camera show the successful rotation of ∇T. Further calibration experiments will be presented.

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

MA 20.22 Tue 9:30 Poster A

Investigation of the tunnel magneto-Seebeck effect via I-V curve symmetries of heated and non-heated Magnetic Tunnel Junctions — •Torsten Huebner[1], Alexander Boehnke[1], Marvin von der Ehe[2], Markus Münzenberg[2], Timo Kuschel[1], and Günter Reiss[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]Greifswald University, Germany

The Seebeck coefficient of a Magnetic Tunnel Junction (MTJ) depends on its magnetic state known as the tunnel magneto-Seebeck effect (TMS) [1]. It has been extensively studied with indirect Joule and laser induced heating [2][3]. Zhang et al. [4] proposed a third method using the intrinsic Joule heating by the tunneling current generated by a bias voltage without any external temperature gradient. Thus, they extract the Seebeck coefficients by evaluating the symmetric contribution of the I-V curves. Here, we investigate I-V curves of CoFeB/MgO/CoFeB MTJs obtained with and without external laser heating. Thus, we are able to identify tunneling currents originating solely from the induced temperature gradient by taking the difference between the signals from the heated and non-heated MTJ. The symmetric and antisymmetric contribution of the I-V curves for various laser heating powers are discussed in detail.

[1] Walter et al., Nat. Mater 10, 742 (2011)
[2] Liebing et al., Phys. Rev. Lett. 107, 177201 (2011)
[3] Boehnke et al., Rev. Sci. Instrum. 84, 063905 (2013)
[4] Zhang et al., Phys. Rev. Lett. 109, 037206 (2012)

MA 20.23 Tue 9:30 Poster A

Magneto-Seebeck Effect in Magnetic Tunnel Junctions with different barriers — •Ulrike Martens[1], Marvin von der Ehe[1], Jakob Walowski[1], Stefan Niehörster[2], Alexander Böhnke[2], Savio Fabretti[2], Karsten Rott[2], Günter Reiss[2], Andy Thomas[2], and Markus Münzenberg[1] — [1]Inst. f. Phys., Ernst-Moritz-Arndt-Universität Greifswald, Germany — [2]CSMD, Physics Department, Bielefeld University, Germany

The first measurements of the tunnel magneto-Seebeck effect (TMS) were reported on magnetic tunnel junctions (MTJs) with a crystalline MgO barrier [1, 2]. Later, Lin *et al.* have observed the TMS effect in MTJs with Al_2O_3 tunnel barriers [3]. They found a correlation between TMR and TMS that were in the same range and giant thermovoltages of 1 mV, both explained by non-magnetic resonance in the tunnel spectrum responsible for the large thermoelectric effects. For the samples investigated for this presentation, the tunnel magnetoresistance (TMR) and the tunnel magneto-Seebeck effect (TMS) were measured. The MTJs are heated by a modulated diode laser which achieves powers of up to 150 mW. The laser is focused onto the sample in a standard confocal microscope setup. We investigate the power dependence of the TMS ratios. For the different materials, the TMS dependence on the applied bias voltage is studied as well. The first results are used to compare the various barrier materials.

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[2] Liebing, N., et al.; Phys. Rev. Lett. 107, 177201 (2011)
[3] Lin, W., et al.; Nat. Commun. 3, 744 (2012)

MA 20.24 Tue 9:30 Poster A

Different temperature and Co thickness dependencies of the anomalous Hall and Nernst effect in Co/Pd multilayers — •Michael van Straaten, Tristan Matalla-Wagner, Daniel Meier, Jan-Michael Schmalhorst, Timo Kuschel, and Günter Reiss — CSMD, Physics Department, Bielefeld University, Germany

The Hall and Nernst effects are related due to a corresponding electrically and thermally induced transport behavior. The anomalous parts of these effects (AHE and ANE) are affected by the magnetization. Therefore, they show a hysteresis of the voltage, which is antisymmetric with respect to the external field. In perpendicularly magnetized Co/Pd multilayers the AHE has a temperature and Co thickness dependent sign change in the voltage [1].

In this work we describe an experimental setup for a simultaneous detection of transverse voltages generated by the AHE and the ANE. By applying a voltage parallel to the in-plane temperature gradient, both effects can be separated by a subsequent measurement with reversed electrical current. Two series of samples with different Co thicknesses are tested. The observed voltage changes with varying thicknesses and temperatures. The results are discussed to point out the fundamentally different behavior between the AHE and ANE in these multilayer systems.

[1] V. Keskin et al., Appl. Phys. Lett. 102, 022416 (2013)

MA 20.25 Tue 9:30 Poster A

Linear and quadratic Nernst effects in a CoFeTb thin film — •Tristan Matalla-Wagner[1], Daniel Meier[1], Zoe Kugler[1], Jaroslav Hamrle[2], Günter Reiss[1], and Timo Kuschel[1] — [1]CSMD, Physics Department, Bielefeld University, Germany — [2]VSB - Technical University of Ostrava, Czech Republic

Nernst effects describe the generation of charge voltages driven by temperature gradients and can occur as side effects in spin Seebeck experiments [1,2]. We investigated the angle dependence of Nernst voltages for various external magnetic field directions on a 30 nm thick Cobalt-Iron-Terbium alloy thin film. We further separated the measured curves into antisymmetric and symmetric parts with respect to the external magnetic field. This method can be used to identify effects which have linear or quadratic dependencies with respect to either the magnetization of the sample or the external magnetic field, such as the linear and quadratic Nernst effect (LNE/QNE). This method was

already used by Meier et al. [3] to separate the anomalous from the planar Nernst effect of a permalloy sample with a platinum strip on it. The separation method combined with the angle dependence is used to investigate the contribution of LNE and QNE to the total Nernst voltage. Furthermore, we discuss how a misalignment of the effective direction of the temperature gradient affects the LNE and the QNE.
[1] D. Meier et al., Phys. Rev. B 87, 054421 (2013)
[2] M. Schmid et al., Phys. Rev. Lett. 111, 187201 (2013)
[3] D. Meier et al., Phys. Rev. B 88, 184425 (2013)

MA 20.26 Tue 9:30 Poster A

***Ab initio* investigation of the tunneling magneto Seebeck effect** — •Christian Franz, Michael Czerner, and Christian Heiliger — I. Physikalisches Institut, Justus Liebig University, Giessen, Germany

The Seebeck coefficient describes the thermoelectric voltage induced in a junction by a temperature gradient. In a magnetic tunnel junction the Seebeck coefficient depends on the relative orientation of the magnetizations; this effect is termed tunneling magneto-Seebeck effect (TMS). The TMS has been predicted theoretically [1] and confirmed experimentally [2].

In this contribution we investigate the TMS in MgO-based tunnel junctions using *ab initio* methods [3]. We investigate the TMS for Fe_xCo_{1-x} leads [4,5] with varying alloy composition, barrier thickness, temperature, and applied bias voltage. We find that the TMS depends sensitively on the parameters, in particular the alloy composition. This behavior can be traced back to the respective dependence of the transmission function. We also show recent results using Heusler alloys for the leads.
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[2] M. Walter et. al, Nat. Mater. 10, 742 (2011).
[3] C. Franz, M. Czerner, C. Heiliger, J. Phys.: Condens. Matter 25, 425301 (2013).
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MA 20.27 Tue 9:30 Poster A

Spin-wave modes and grating coupler effect in bicomponent magnetic periodic lattices of different topology — •Stefan Mändl[1], Florian Heimbach[1], Haiming Yu[1,2], and Dirk Grundler[1] — [1]Physik Department E10, TU München, Garching, Germany — [2]present address: Spintronics Interdisciplinary Center, Beihang University, China

Recently the so called magnonic grating coupler (MGC) effect was observed in bicomponent magnetic lattices consisting of e.g. a two-dimensional (2D) array of Py nanodisks partly embedded in a CoFeB thin film. [Yu13] It was shown that the periodic lattice provoked backfolding of the fundamental mode. We present spin-wave spectroscopy and simulations on bicomponent MGCs where we inverted the materials composition and varied the structural composition (topology) to optimize the backfolding effect. In experiments on 2D arrays of CoFeB nanodisks integrated to a Py film a series of spin-wave resonances were resolved that we attributed to MGC modes radiated in up to 16 different directions. This way a spin-wave nanograting coupler with almost omnidirectional spin-wave emission was created. We provide microscopic insight into the MGC performance by comparing micromagnetic simulations and spectroscopy data. The work was funded by the Cluster of Excellence Nanosystems Initiative Munich and in the SPP 1538 via GR1640/5.

[Yu13] H. Yu, G. Duerr, R. Huber, M. Bahr, T. Schwarze, F. Brandl, D. Grundler, Omnidirectional spin-wave nanograting coupler, Nature Communications 4, 2702 (2013)

MA 20.28 Tue 9:30 Poster A

Spin pumping inverse spin Hall effect and spin transfer torque ferromagnetic resonance in NiFe/Pt and NiFe/Ta bilayers — •Islinger Robert, Obstbaum Martin, Härtinger Markus, and Back Christian H. — Institute for Experimental and Applied Physics, University Regensburg, 93040 Regensburg, Germany

Spin pumping in NiFe/normal metal bilayers together with the inverse spin Hall effect (SP-ISHE) constitutes a reliable method for determining spin Hall angles α_{SH} [1]. Another method to determine α_{SH} is the spin transfer torque ferromagnetic resonance (STT-FMR) technique recently introduced by Liu et al for ferromagnet/normal metal bilayers [2,3]. Whereas for platinum (Pt) both SP-ISHE and STT-FMR yield consistent results for tantalum (Ta) the two methods are contradictory. We present an extensive study of SP-ISHE and STT-FMR for both Pt and Ta. The two methods will be explained in detail and possible physical explanations for conflicting results will be discussed. [1] M. Obstbaum et al., Phys. Rev. B 89, 060407 (R) (2014) [2] L. Liu et al., Phys. Rev. Lett. 106, 036601 (2011) [3] L. Liu et al., Science 336, 555 (2012)

MA 20.29 Tue 9:30 Poster A

Asymmetric spin wave dispersion relation due to interfacial Dzyaloshinskii-Moriya interaction — •Helmut Körner[1], Johannes Stigloher[1], Hans Bauer[1], Hiroshi Hata[2], Takuya Taniguchi[2], Takahiro Moriyama[2], Teruo Ono[2], and Christian Back[1] — [1]Department of Physics, Regensburg University, 93053 Regensburg, Germany — [2]Laboratory of Nano Spintronics, Division of Materials Chemistry, Institute for Chemical Research, Kyoto University, Uji, Kyoto 611-0011, Japan

The interfacial Dzyaloshinskii-Moriya interaction (DMI) has attracted much attention lately due to its possible usage in future spintronic devices. It occurs in any trilayer structure when the first nonmagnetic layer provides spin-orbit coupling, the middle layer is a ferromagnet, and the third layer is nonmagnetic, but different from the first layer to break symmetry.

In our experiment, we study propagating magnetostatic spin waves in the Damon-Eshbach geometry by means of time-resolved scanning Kerr microscopy in 70 μm wide Ta(2)/Pt(2)/Co(0.4)/Py(5)/MgO(5) stripes. Due to the DMI present at the Pt/Co interface, an asymmetry in the spin wave dispersion relation is expected with respect to both their propagation direction and the equilibrium magnetization direction [1,2]. From the observed asymmetry in the shift in the wave-vector amplitude we can quantify the DMI in our system.

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MA 20.30 Tue 9:30 Poster A

Investigation of spin waves dispersion in Co thin films on W(110) from first-principles — •Flaviano José Dos Santos, Manuel Dos Santos Dias und Samir Lounis — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

We perform first-principles calculations based on the Korringa-Kohn-Rostoker Green functions method in order to extract the magnetic exchange interactions for Co thin films on W(110) surface. We analyze the strength and oscillatory behavior of the intra-layer and inter-layer magnetic interactions and investigate the resulting dispersion of spin waves as a function of the thickness of Co films. We compare our results to previous [1] and recent [2] measurements based on electron energy loss spectroscopy. In particular, we demonstrate the strong impact of hybridization of the electronic states at the interface of Co and W on the magnetic exchange interactions and on the spin-waves dispersion curve.

Work supported by the Coordenadoria de Aperfeiçoamento de Pessoal de Nível Superior - CAPES (BRAZIL) and HGF-YIG Programme FunSiLab - Functional Nanoscale Structure Probe and Simulation Laboratory (VH-NG-717). [1] M. Etzkorn, P. S. Anil Kumar, W. Tang, Y. Zhang, and J. Kirschner, Phys. Rev. B **72**, 184420 (2005). [2] E. Michel, H. Ibach, and C. M. Schneider, private communication.

MA 20.31 Tue 9:30 Poster A

Interfacial spin-orbit effect in Ta/CoFeB/MgO — •Gurucharan V. Karnad[1], Roberto Lo Conte[1,2], Eduardo Martinez[3], Ales Hrabec[4], Andrei P. Mihai[4], Tomek Schulz[1], Christopher H. Marrows[4], Thomas A. Moore[4], and Mathias Kläui[1,2] — [1]Johannes Gutenberg Universität-Mainz, Institut für Physik, Staudinger Weg 7, 55128 Mainz, Deutschland — [2]Graduate School of Excellence Materials Science in Mainz (MAINZ), Staudinger Weg 9, 55128 Mainz, Deutschland — [3]Universidad de Salamanca, Plaza de los Caidos s/n E-37008, Salamanca, Spain — [4]School of Physics and Astronomy, University of Leeds, Leeds LS2 9JT, U.K.

Spin-orbit effects in out-of-plane magnetized materials have been an area of intense research due to efficient current induced domain wall motion (CIDWM) and current induced magnetization switching (CIMS) observed in these systems. Here we report the measurements of spin-orbit torques and Dzyaloshinskii-Moriya interaction (DMI) in heavy metal(HM)/ ferrmomagnet(FM)/oxide(Ox)systems.We found the DW velocity to be strongly affected by the presence of a longitudinal magnetic field, resulting in a different velocity for the up-down and down-up domain walls at fixed current densities and magnetic fields. These results can be interpreted by the spin-Hall effect-torque model [1,2], where the chirality of the domain walls is fixed by the DMI at the HM/FM interface.

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[2]K.-S. Ryu,et al., Nat. Nanotech.8, 527-533 (2013).

MA 20.32 Tue 9:30 Poster A

Spin Wave Doppler Experiments using Current Modulation — •Johannes Stigloher, Helmut Körner, Hans Bauer, Jean-Yves Chauleau, and Christian Back — Department of Physics, Regensburg University, 93053 Regensburg, Germany

Spin transfer torques (STT) have been an active field of research for the last 20 years and arise when an electric current interacts with a non-homogenous region of magnetic texture such as magnetic domain walls, magnetic vortex cores or spin waves. In the latter case a spin wave Doppler shift can be observed [1]. It was shown already that this technique enables a self-consistent determination of the key STT parameters [2] on one single sample. Here, we modify the technique presented in [2] by the modulation of the electric current at a low frequency and subsequent detection using two lock-in amplifiers. Hence, we achieve a substantial noise reduction along with a direct access to the effect of the electric current on spin wave characteristics. Furthermore, this approach offers the possibility to determine the temperature dependence of the key STT parameters.

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[2] J.-Y. Chauleau et al., Phys. Rev. B. 89, 020403(R) (2014)

MA 20.33 Tue 9:30 Poster A

Dynamics and inertia of skyrmionic spin structures — F. Büttner[1,2,3], C. Moutafis[4], •B. Krüger[1], M. Schneider[3], C. M. Günther[3], J. Geilhufe[5], C. von Korff Schmising[3], J. Mohanty[3], A. Bisig[1], M. Foerster[1], T. Schulz[1], C. A. F. Vaz[1,6], J. H. Franken[7], H. J. M. Swagten[7], M. Kläui[1], and S. Eisebitt[3,5] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, Mainz, Germany — [2]Graduate School Materials Science in Mainz, Mainz, Germany — [3]Institut für Optik und Atomare Physik, Technische Universität Berlin, Berlin, Germany — [4]Swiss Light Source, Paul Scherrer Institut, Villigen PSI, Switzerland — [5]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Berlin, Germany — [6]SwissFEL, Paul Scherrer Institut, Villigen PSI, Switzerland — [7]Department of Applied Physics, Eindhoven University of Technology, Eindhoven, The Netherlands

In nano-patterned magnetic thin-film elements bubble skyrmions emerge. Their magnetization points out-of-plane opposite to the remaining part. The dynamics of these structures resembles that of composite quasi-particles. Magnetic bubbles are skyrmions characterized by the topology of their spin vector field. Here, we study the GHz gyrotropic motion of a skyrmion spin structure experimentally using pump-probe X-ray holography. Tracking the bubble position with 3 nm accuracy we report the first experimental observation of the GHz gyrotropic motion of a skyrmion. We found that the inertial mass of the magnetic bubble is much larger than inertia found in any other magnetic system. [F. Büttner, et al., Nature Phys. (accepted)]

MA 20.34 Tue 9:30 Poster A

intuitive explanation of anisotropic magnetoresistance (AMR) effect and necessary condition for half-metallic ferromagnet "negative AMR" — •satoshi kokado[1], yuta kitagawa[1], takuya ito[1], and masakiyo tsunoda[2] — [1]Graduate School of Engineering, Shizuoka University, Hamamatsu, Japan — [2]Graduate School of Engineering, Tohoku University, Sendai, Japan

The anisotropic magnetoresistance (AMR) effect is a phenomenon in which the electrical resistivity depends on the relative angle between the magnetization direction and the electric current direction. The AMR ratio, which is the efficiency of the effect, is defined by $(\rho_{//} - \rho_{\perp})/\rho_{\perp}$. Here, $\rho_{\parallel}$ ($\rho_{\perp}$) represents a resistivity for the case of the electrical current parallel to the magnetization (a resistivity for the case of the current perpendicular to the magnetization). The AMR effect has been experimentally studied for various ferromagnets since about 150 years ago. The intuitive explanation about the AMR effect, however, has scarcely been reported. In this study, we first derive a general expression of the AMR ratio extending the conventional model to a more general one [1 - 3]. Using the general expression, we next give the intuitive explanation about the AMR effect [2]. In addition, we show that the negative AMR ratio is a necessary condition for half-metallic ferromagnets [1, 2].

[1] S. Kokado *et al.*, J. Phys. Soc. Jpn. **81** 024705 (2012).
[2] S. Kokado *et al.*, Adv. Mater. Res. **750-752** 978 (2013).
[3] S. Kokado *et al.*, Phys. Status Solidi C **11** 1026 (2014).

MA 20.35 Tue 9:30 Poster A

Towards a straightforward semiclassical ab initio description of the side-jump mechanism in the SHE — •Christian Herschbach[1,2], Dmitry Fedorov[2,1], Martin Gradhand[3], and Ingrid Mertig[1,2] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [3]H. H. Wills Physics Laboratory, University of Bristol, Bristol, United Kingdom

The investigations of the spin Hall effect rely on the separation between intrinsic and extrinsic contributions, where the latter ones imply the skew-scattering and side-jump mechanisms. While the first-principles description of the skew scattering was already successfully implemented [1], a corresponding semiclassical approach for the side-jump mechanism is still missing.

We present a first step into this direction by considering two different simplified approaches. The first one follows a suggestion of Sinitsyn et al. [2] focussing on the host properties expressed in terms of the Berry curvature, which is calculated from first principles [3]. The second approach puts the emphasis on the properties of the impurities by extending the resonant scattering model [4] similarly to the case of skew scattering [5]. Here, the required scattering phase shifts are obtained by means of *ab initio* calculations.

[1] M. Gradhand *et al.*, PRL **104**, 186403 (2010); [2] N.A. Sinitsyn *et al.*, PRB **73**, 075318 (2006); [3] M. Gradhand *et al.*, PRB **84**, 075113 (2011); [4] A. Fert and P.M. Levy, PRL **106**, 157208 (2011); [5] D.V. Fedorov *et al.*, PRB **88**, 085116 (2013).

MA 20.36 Tue 9:30 Poster A

Spin-curvature and local density of states in PdFe/Ir(111) — Christian Hanneken[1], •André Kubetzka[1], Niklas Romming[1], Kirsten von Bergmann[1], Roland Wiesendanger[1], Fabian Otte[2], Bertrand Dupé[2], and Stefan Heinze[2] — [1]Department of Physics, University of Hamburg — [2]Institute of Theoretical Physics and Astrophysics, University of Kiel

In many magnetic systems the spin-averaged local density of states (LDOS) depends on the magnetization direction due to spin-orbit interaction. This effect can be measured e.g. with scanning tunneling spectroscopy and is typically on the order of 10% [1].

Here we employ the same technique to investigate the influence of the magnetic non-collinearity (spin-curvature) in a PdFe bilayer on Ir(111) [2,3] onto the LDOS measured in the vaccum above the surface. The effect is surprisingly strong and can be tuned by changing the spin-curvature of a skyrmion in applied magnetic fields. Tight-binding calculations show that it stems from the mixing between majority and minority spin bands which scales with the local spin-curvature.

[1] M. Bode *et al.*, Phys. Rev. Lett. **89**, 237205 (2002).
[2] N. Romming *et al.*, Science **341**, 636 (2013).
[3] B. Dupé *et al.*, Nature Commun. **5**, 4030 (2014).

MA 20.37 Tue 9:30 Poster A

Spin Seebeck effect in the GHz regime — •Franz Kramer[1,2], Michael Schreier[1,2], Hans Huebl[1,3], Stephan Geprägs[1], Rudolf Gross[1,2,3], and Sebastian T. B. Goennenwein[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, TU München, Garching, Germany — [3]Nanosystems Initiative Munich, München, Germany

In the spin Seebeck effect(SSE) experiments pure spin currents are generated via a thermal nonequilibrium at the interface between a ferromagnet and a normal metal. Time-resolved SSE experiments allow to gain insight into the microscopic origin of the spin current generation, but published results are inconclusive.[1,2] We revisit our previous time-resolved Spin Seebeck effect studies[1] and expand the frequency range of the temperature modulation up to several Gigahertz, corresponding to time constants below one nanosecond. This also gives insight into a potential thickness dependence of the spin Seebeck effect as reported earlier,[3] as the thermal length (determining the volume in which the temperature modulation occurs) is of the order of some ten nanometers for GHz frequencies . We present our recent results and critically discuss them in view of the existing SSE models.

[1]Roschewsky et al., Appl. Phys. Lett **104**, 202410 (2014),
[2]Agrawal et al.,Phys. Rev. B **89**, 224414 (2014),
[3]Kehlberger et al., arXiv:1306.0784

MA 20.38 Tue 9:30 Poster A

Anomalous Hall Effect within a phase shift model — •Albert Hönemann[1], Christian Herschbach[1,2], Dmitry Fedorov[2,1], Martin Gradhand[3], and Ingrid Mertig[1,2] — [1]Martin Luther University Halle-Wittenberg, Halle, Germany — [2]Max Planck Institute of Microstructure Physics, Halle, Germany — [3]University of Bristol, Bristol, United Kingdom

The spin Hall effect (SHE) and the anomalous Hall effect (AHE) are closely related transport phenomena both caused by spin-orbit coupling (SOC). Their straightforward theoretical description requires rigorous but demanding *ab initio* calculations based on relativistic codes. Recently, phase shift models [1,2] were developed as a generalization of the resonant scattering models [3-6]. They provide a simplified description of the SHE with a good qualitative agreement to first-principles results obtained for dilute alloys based on host crystals with free-electron like Fermi surfaces and weak SOC [7].

Here, we employ these phase shift models for a description of the AHE caused by 3*d* impurities in noble metals. The obtained results are compared to the corresponding *ab initio* calculations performed within a semiclassical approach of Ref. [8].

[1] Fedorov *et al.*, PRB **88**, 085116 (2013); [2] Herschbach *et al.*, PRB **88**, 205102 (2013); [3] Fert *et al.*, J. Magn. Magn. Mater. **24**, 231 (1981); [4] Guo *et al.*, PRL **102**, 036401 (2009); [5] Fert and Levy, PRL **106**, 157208 (2011); [6] Levy *et al.*, PRB **88**, 214432 (2013); [7] Johansson *et al.*, J. Phys.: Condens. Matter **26**, 274207 (2014); [8] Zimmermann *et al.*, arXiv:1406.2712.

MA 20.39 Tue 9:30 Poster A

Correlating spin orbit effects and structural inversion asymmetry in multilayer stacks — •Samridh Jaiswal[1,2], Berthold Ocker[2], Gerhard Jakob[1], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]SINGULUS TECHNOLOGIES AG, Hanauer Landstrasse 103, 63796 Kahl am Main, Germany

Recently there has been wide spread interest to exploit multilayer materials and use them for memory and logic devices based on current-induced magnetization dynamics. One of the associated problems to overcome is being able to achieve low threshold currents for switching of the magnetic state and to achieve a high thermal stability in these devices. A possible solution to solve the issues associated with memory based devices is to achieve a strong perpendicular magnetic anisotropy[1] and then to use Structural Inversion Asymmetry (SIA) in multilayers to study the effects of Spin Orbit Torques(SOTs) in the presence of the Dzyaloshinskii Moriya interaction. Current induced magnetization switching is gathering much interest as a means of low power magnetic switching and relies on the spin orbit effects in these materials [2]. In this contribution we investigate the growth of multilayer stacks with SIA and we discuss the effects of the underlayers on the magnetic anisotropy and the viability to use these materials for studying SOTs. Financial support by the EU Marie Curie ITN project WALL is gratefully acknowledged.

[1] Yang, H. X. et al. Phys. Rev. B, 84, 054401 (2011) [2] Lo Conte, R. et al , Appl. Phys. Lett., 105, 122404 (2014)

MA 20.40 Tue 9:30 Poster A

The tunnel magnetoresistance and shot noise of triple quantum dots in the sequential and cotunneling regimes — •Kacper Wrześniewski and Ireneusz Weymann — Faculty of Physics, Adam Mickiewicz University in Poznań, ul. Umultowska 85, 61-614 Poznań, Poland

We study the spin-dependent transport through a coherent triple quantum dot system weakly coupled to external ferromagnetic electrodes. The calculations are performed with the aid of the real-time diagrammatic technique up to the second order of the perturbation theory with respect to the coupling to the leads. We discuss the behavior of the current, tunnel magnetoresistance and shot noise in both the linear and nonlinear response, focusing on the role of cotunneling processes. It is shown that, depending on the device geometry, parameters of the model and applied voltages, the system can exhibit negative tunnel magnetoresistance, negative differential conductance and super-Poissonian shot noise. The mechanisms leading to the above effects are thoroughly analyzed.

MA 20.41 Tue 9:30 Poster A

Domain wall motion in a ferromagnet induced by pure diffusive spin currents in graphene — •Fabienne Musseau[1], Michele Voto[2], Alexander Pfeiffer[1], Nils Richter[1], Luis Lopez Diaz[2], and Mathias Kläui[1] — [1]Institut für Physik, Johannes Gutenberg-Universität Mainz, 55099 Mainz, Germany — [2]Departamento de Física Aplicada, Universidad de Salamanca, 37008 Salamanca, Spain

Due to the miniaturization of systems to the nanoscale, the physics of surfaces and interfaces is a major area of research. On the applications side, novel storage concepts, such as the racetrack memory use spin currents [1] in ferromagnetic nanowires where data is encoded as a pattern of magnetic domains. Alternatively synchronous motion of domains can also be obtained by special field geometries [2]. Another possibility is to use pure diffusive spin currents to manipulate the magnetization in a ferromagnet [3,4]. As here the limitation is the spin transport in the spin conduit, we use graphene as due to its low spin-orbit coupling and high mobility a large spin diffusion length ensues, allowing for large spin currents [5]. We investigate the displacement of domain walls via spin torques exerted by pure diffusive spin currents in a non-local spin valve geometry [3,4]. We compare our results to micromagnetic simulations to understand the acting torques.

References [1] Parkin et al., Science 320, 190 (2008) [2] Kim et al., Nat. Commun. 5, 3429 (2014) [3] Motzko et al., Phys. Rev. B, 88, 214405 (2013) [4] Ilgaz et al., Phys. Rev. Lett. 105, 076601 (2010) [5] Tombros et al., Nature 448, 571 (2007)

MA 20.42 Tue 9:30 Poster A

Dependence of the spin Hall magnetoresistance on ferromagnet surface termination and thickness — •Hannes Maier-Flaig[1,2], Stephan Geprägs[1], Rudolf Gross[1], and Sebastian T.B. Goennenwein[1,3] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, 85748 Garching, Germany — [2]Physik - Department, TU München, Garching, Germany — [3]Nanosystems Initiative Munich, 80799 München, Germany

In recent years, considerable efforts have been made to understand the effect of interface properties on the transport of (spin) angular momentum across the interface between an insulating ferromagnet and a normal metal [1]. The recently discovered spin Hall magnetoresistance (SMR)[2] describes the impact of spin current flow on the resistance of the metal. We use magnetization orientation dependent SMR measurements to investigate the dependence of this effect in $Y_3Fe_5O_{12}$|Platinum (YIG|Pt) heterostructures. In particular, we study the impact of surface termination and magnetic layer thickness on spin current transport. More specifically, we deposited Pt layers insitu on epitaxially grown YIG films with thicknesses down to a single unit cell. The crystalline orientation (and thus the different interface termination), as well as the thickness of the YIG layers was systematically varied. We discuss how the SMR depends on these parameters and address the impact of the interface termination. This work was supported by the DFG via SPP 1538 (project no. GO 944/4).

[1] Weiler *et al.*, Phys. Rev. Lett. 111, 176601 (2013)
[2] Nakayama *et al.*, Phys. Rev. Lett 110, 206601 (2013)

MA 20.43 Tue 9:30 Poster A

Anisotropic interface contributions to the magnetothermoelectric power (MTEP) in Co/Pt layered structures — Axel Frauen, André Kobs, Tim Böhnert, Ann-Kathrin Michel, •Afsaneh Farhadi, Kornelius Nielsch, and Hans Peter Oepen — Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstr. 11a, 20355 Hamburg, Germany

We report on the magnetothermoelectric power (MTEP) and magnetoresistance (MR) of Co/Pt films. Regarding the MR measurements, the in-plane rotation of magnetization $\mathbf{M}$ reveals the bulk-like anisotropic MR (AMR). The corresponding thermoelectric counterpart is observed in the Seebeck voltage U_S when an in-plane temperature gradient ∇T is applied. This is the conventional anisotropic MTEP effect, which is predicted to occur in the Seebeck coefficient $S = -U_S/\Delta T$ according to Mott's formula [1]: $S(\mathbf{M}) \propto [1/\rho(E,\mathbf{M}) \cdot \mathrm{d}\rho(E,\mathbf{M})/\mathrm{d}E]_{E=E_\mathrm{F}}$ (Fermi energy E_F). A linear $S(1/\rho)$ behavior is found revealing that $[\mathrm{d}\rho(E,\mathbf{M})/\mathrm{d}E]_{E=E_\mathrm{F}}$ does not depend on $\mathbf{M}$ in accordance with Ref. [1]. Moreover, we observe that U_S also depends on the orientation of $\mathbf{M}$ within the plane perpendicular to ∇T. This characteristic is the thermoelectric counterpart of the recently discoverd anisotropic interface MR (AIMR) [2]. Also for the AIMR and its thermoelectric counterpart a linear $S(1/\rho)$ curve is found. Interestingly, both $S(1/\rho)$ curves exhibits different slopes, which implies that $[\mathrm{d}\rho(E,\mathbf{M})/\mathrm{d}E]_{E=E_\mathrm{F}}$ and therefore the band structure is significantly different for Co/Pt interfaces compared to Co bulk. [1] Avery et al., PRB **86**, 184408 (2012), [2] Kobs et al., PRL **106**, 217207 (2011).

MA 20.44 Tue 9:30 Poster A

Field and temperature dependence of spin fluctuations in $ZrZn_2$ — •Pascal Reiss, Gilbert Lonzarich, and F Malte Grosche — Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, United Kingdom

$ZrZn_2$ is a low temperature band ferromagnet ($T_c \approx 28$ K), which displays non-Fermi liquid transport properties over a wide temperature range: above $T_{FL} \approx 1K$ and even beyond T_c, the electrical resistivity follows a power-law temperature dependence with an exponent 5/3, whereas the electronic contribution to the thermal resistivity is linear in temperature. This has been explained in terms of a magnetic fluctuation model, which includes a self-consistent renormalisation for the magnetic susceptibility [1, 2]. Applied magnetic fields up to 9 T have been observed to increase the cross-over temperature T_{FL} to ≈ 7 K. Previous calculations did not include effects of magnetic fields.

We will present the results of an extended calculation which accounts for the role of applied field, allowing a comparison between high field resistivity measurements and the predictions of a magnetic fluctuation model. Furthermore we will show that the magnetic transition is expected to be continuous in this model. However this transition is characterised by a strongly temperature dependent coefficient $b(T)$ of the quartic term in a Landau-Ginzburg expansion. Moreover, $b(T)$ changes sign at T_c, with $b(T) < 0$ in the ordered phase.

[1] G. G. Lonzarich and L. Taillefer, J Phys C: Solid State Phys, **18**, 4339-4371 (1985)

[2] R. Smith et al., Nature, **455**, 1220-1223 (2008)

MA 20.45 Tue 9:30 Poster A

Capturing a Skyrmion with a Hole — •Jan Müller and Achim Rosch — Institut für Theoretische Physik, Universität zu Köln, Deutschland

Stable magnetic whirls in chiral magnets, so-called skyrmions, can be manipulated by ultrasmall current densities. We study both analytically and numerically the interactions of a single skyrmion in two dimensions with a small hole in the magnetic layer. Results from micromagnetic simulations are in good agreement with effective equations of motion obtained from a generalization of the Thiele approach. Skyrmion-defect interactions are described by an effective potential with both repulsive and attractive components.

For small current densities a previously pinned skyrmion stays pinned whereas an unpinned skyrmion moves around the impurities and never gets captured. For higher current densities, however, single holes are able to capture moving skyrmions. The maximal cross section is proportional to the skyrmion radius and to the square root of the Gilbert damping. For large currents all skyrmions are depinned. Small changes of the magnetic field strongly change the pinning properties, one can even reach a regime without pinning at all. We also show that a small density of holes can effectively accelerate the motion of the skyrmion and introduce a Hall effect for the skyrmion.

MA 20.46 Tue 9:30 Poster A

Dipole-Dipole Interactions in Skyrmionic Systems — •Lukas Heinen and Achim Rosch — Institut für theoretische Physik, Universität zu Köln, Deutschland

Chiral magnets exhibit vortex-like excitations of the magnetic structure, so-called skyrmions. These excitations carry an integer winding number and hence are stabilized by topological protection. Furthermore they can be manipulated with ultra-low current densities. Therefore skyrmions are a promising candidate for the development of spintronic devices.

Skyrmions in chiral magnets are mainly driven by Dzyaloshinksii-Moriya (DM) interactions. In typical skyrmion materials, like MnSi, dipole-dipole interactions are nominally of similar magnitude as DM interactions. However, they influence *static* skyrmion properties only weakly, due to the specific form of the magnetic structure of skyrmions. We study how the inclusion of the full dipole-dipole interactions changes the *dynamical* properties of skyrmions. Using micro-magnetic simulations of thin films, we compute the change in the phase diagram, the effective skyrmion-defect-interaction potential, and the excitation spectrum.

MA 20.47 Tue 9:30 Poster A

Current-induced effects in YIG/Pt heterostructures — •Johannes Mendil[1], Kevin Garello[1], Can Onur Avci[1], Morgan Trassin[2], Manfred Fiebig[2], and Pietro Gambardella[1] — [1]ETH Zurich, Department of Materials, Magnetism and Interface Physics, Hönggerbergring 64, CH-8093 Zürich, Switzerland — [2]ETH Zurich, Department of Materials, Multifunctional Ferroic Materials, Vladimir-Prelog-Weg 4, CH-8093 Zürich, Switzerland

Yttrium Iron Garnet (YIG)/heavy metal bilayers have attracted considerable interest in the field of spintronics due to the possibility of inducing spin currents by magnon excitation and vice versa. In this work, we report on current-induced effects that arise from the interplay of the magnetization in YIG and spin currents generated in Pt. YIG thin films have been prepared by pulsed laser deposition on Gadolinium Gallium Garnet (GGG) substrates followed by in-situ sputtering of 6 nm-thick Pt. We present results on the harmonic analysis of current-induced spin-orbit torques in YIG films of variable thickness.