MA 48: Spin Dynamics and Transport: Spin Excitations and Spin Torque Phenomena

Time: Thursday 9:30–13:15 Location: HSZ 101

MA 48.1 Thu 9:30 HSZ 101

Micron sized tapered spin hall oscillators under the influence of external microwave signals — •Kai Wagner[1,2], Andrew Smith[3], Tobias Hula[1], Toni Hache[1], Jürgen Lindner[1], Ilya Krivorotov[3], and Helmut Schultheiss[1,2] — [1]HZDR, Institute of Ion Beam Physics and Materials Research, D-01328, Germany — [2]TU Dresden, D-01062 Dresden, Germany — [3]Department of Physics and Astronomy, University of California, Irvine, California, USA.

We investigate by Brillouin-Light-Scattering microscopy the spatial dependent auto-oscillation spectra of tapered permalloy wires [1] when subjected to spin-orbit-torques generated via the spin hall effect in an underlying Platinum layer. We first identify the different spectral contributions to the integral auto-oscillation signal across the spatially varying SHO. Subsequently the influence of external microwave signals on these spectra are investigated. Strongly amplified signals are observed, when the microwave frequency matches those of the auto-oscillations even for microwave powers, which are sufficiently small to not excite magnetisation dynamics outside of the auto-oscillatory regime. We believe this can be attributed to locking of the non-isochronus SHO to the external microwave signals resulting in spectrally narrower auto-oscillations with differing spatial extend. The authors acknowledge financial support from the Deutsche Forschungsgemeinschaft within programme SCHU 2922/1-1.

[1]: Liu Yang et al. , Scientific reports **5**, 16942 EP, 2015

MA 48.2 Thu 9:45 HSZ 101

Spin-wave heating vs. Joule heating in spin-Hall-effect and spin-transfer-torque driven Cr|Heusler|Pt waveguides — •Thomas Meyer[1], Philipp Pirro[1], Thomas Brächer[1,3], Frank Heussner[1], Alexander Serga[1], Hiroshi Naganuma[2], Koki Mukaiyama[2], Mikihiko Oogane[2], Yasuo Ando[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Applied Physics, Graduate School of Engineering, Tohoku University, Sendai 980-8579, Japan — [3]current affiliation: Université Grenoble Alpes, CNRS, CEA, INAC-SPINTEC, 38054 Grenoble, France

We present time-resolved Brillouin light scattering measurements on spin-Hall-effect and spin-transfer-torque driven magnetization dynamics in a microstructured Cr|Heusler|Pt waveguide. Reducing the effective spin-wave damping, a strong increase in the magnon density is observed which is accompanied by a reduction of the spin-wave frequency. By evaluating the temporal behavior of these effects and comparing these to COMSOL multiphysics simulations, we can identify spin waves as the main heating source in the investigated structure. Correlating the spin-wave frequency to the magnon density for different applied current values proves that Joule heating by the applied current can be neglected. The results show that, in any application using the spin-transfer torque effect, the contribution to the temperature increase by an increased magnon density needs to be considered. Financial support by the DFG (TRR 173 'Spin+X') is acknowledged.

MA 48.3 Thu 10:00 HSZ 101

Parametric excitation of magnons in YIG films from cryogenic to above room temperatures — •Laura Mihalceanu[1], Vitaliy I. Vasyuchka[1], Dmytro A. Bozhko[1,2], Thomas Langner[1], Burkard Hillebrands[1], and Alexander A. Serga[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, Germany

Parameric pumping is a powerful tool to study fundamental properties of magnetization dynamics since it allows for the efficient excitation of magnons in a wide range of wavenumbers. By this, the efficient magnon injection into the spin system of yttrium iron garnet (YIG) films enabled the observation of such prominent phenomena as magnon Bose-Einstein condensates (BECs) and magnon supercurrents. Since until now all related experiments have been performed under normal ambient conditions, moving to cryogenic temperatures is of high interest, as a temperature decrease is expected to increase both the density and the lifetime of a magnon BEC significantly. The elongated BEC lifetime will allow to investigate the BEC's dynamics at long time scales and will help to reveal, e.g., such relatively slow effects as Josephson oscillations. As a first step toward low-temperature magnon BECs, we study the parametric excitation of dipolar and exchange magnons in the temperature range from 40 K to 340 K. We address the impact of temperature on the saturation magnetization and reveal the behavior of the magnon relaxation parameter on the wide temperature scale.

The work is supported by the DFG within the SFB/TR 49.

MA 48.4 Thu 10:15 HSZ 101

Auto-oscillations in YIG/Pt nanostructures driven by the spin Seebeck effect — •Viktor Lauer[1], Micheal Schneider[1], Thomas Meyer[1], Philipp Pirro[1], Frank Heussner[1], Carsten Dubs[2], Bert Lägel[1], Vitaliy I. Vasyuchka[1], Alexander A. Serga[1], Burkard Hillebrands[1], and Andrii V. Chumak[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, 67663 Kaiserslautern, Germany — [2]INNOVENT e.V., Technologieentwicklung, Prüssingstraße 27B, 07745 Jena, Germany

We report on experimental investigations of magnetization auto-oscillations excitated in the YIG layer of a YIG/Pt nanowire driven by the spin Seebeck effect (SSE). DC current pulses applied to the nanowire result in Joule heating of the Pt layer, and lead to the formation of a thermal gradient across the YIG/Pt interface. The thermal gradient gives rise to a SSE-induced spin current injected into the YIG layer which exerts an anti-damping torque on the magnetization, and, eventually, excites magnetization precession. Time-resolved Brillouin light scattering microscopy is used to investigate the temporal evolution and spatial distribution of the excited magnetization dynamics in the nanowire. These findings are of interest since they suggest the generation of a coherent precession state from incoherent SSE-injected magnons and reveal a realization of microwave sources at room temperature. This research has been supported by: EU-FET Grant InSpin 612759, ERC Starting Grant 678309 MagnonCircuit, and DFG (DU 1427/2-1, and SE 1771/4-2 within SPP 1538)

MA 48.5 Thu 10:30 HSZ 101

Non-local magnon transport in iron garnet/Pt nanostructures — •Kathrin Ganzhorn[1,2], Tobias Wimmer[1,2], Zhiyong Qiu[3], Stephan Gepraegs[1], Nynke Vlietstra[1], Rudolf Gross[1,2,4], Hans Huebl[1,2,4], Eiji Saitoh[3], and Sebastian T.B. Goennenwein[1,2,4,5] — [1]Walther-Meissner-Institut, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Institute for Materials Research, Tohoku University, Sendai, Japan — [4]Nanosystems Initiative Munich, Munich, Germany — [5]Institut für Festkörperphysik, Technische Universität Dresden, Dresden, Germany

Magnons, the carriers of angular momentum in magnetically ordered systems, are attractive for information transfer and processing. For the realization of corresponding devices, an all-electrical generation and detection of magnons is desirable. Recent experiments in yttrium iron garnet/platinum (YIG/Pt) bilayers show that non-equilibrium magnons can be injected electrically into the insulating YIG by driving a dc charge current through the Pt, via spin scattering mechanisms at the YIG/Pt interface. The magnons propagate through the YIG and are detected as a non-local resistive voltage in a second, electrically isolated Pt strip [1,2]. We study this effect, called magnon-mediated magnetoresistance (MMR), in different iron garnet/Pt systems as a function of the distance between injector and detector, temperature and magnetic field. This work is supported by the DFG via SPP 1538.
[1]L. Cornelissen et al., Nat. Phys. **11**, 1022 (2015) [2]S. T. B. Goennenwein et al., Appl. Phys. Lett. **107**, 172405 (2015)

MA 48.6 Thu 10:45 HSZ 101

Temperature dependent magnon polariton spectroscopy in YIG sphere — •Isabella Boventer[1], Marco Pfirrmann[2], Martin Weides[1,2], and Mathias Kläui[1] — [1]Institute of Physics, Johannes Gutenberg-Universität Mainz, 55128 Mainz — [2]Institute of Physics, Karlsruhe Institute of Technology, 76131 Karlsruhe

For information technology, the spin based approach is a promising candidate for new applications such as data storage and communication. The collective excitation of a spin ensemble results in a spin wave in the microwave (GHz) regime, termed magnon. Experimentally, we interface magnons with microwave cavities to investigate the dynamics within the magnetic system. The sample is a millimetre sized YIG sphere, placed in the 6.5 GHz bright mode of a reentrant cavity. The magnonic elements are strongly coupled to the photonic resonator, resulting in hybridized magnon-resonator states, called magnon polaritons. We have set up an experimental apparatus for the resonant coupling of spin waves in a magnetic bulk or thin film to either inside a microwave cavity or a coplanar waveguide (CPW) in the strong coupling regime [1,2]. This enables both readout at a fixed frequency or broadband measurements employing ferromagnetic resonance (FMR) and input-output theory for temperatures from 5 K to 300 K. We present temperature dependent spectroscopic measurements of the magnon-polariton states. Features of the strongly coupled such as the coupling strength g and linewidth are discussed. [1] Y. Tabuchi, et al., Phys. Rev. Lett. 113, 083603 (2014) [2] X. Zhang, et al., Phys. Rev. Lett 113, 156401 (2014)

MA 48.7 Thu 11:00 HSZ 101

Study of Thermally Tunable Coupled Magnetic Vortex Oscillators with Lorentz Transmission Electron Microscopy and Differential Phase Contrast Microscopy — •Johannes Wild, Michael Vogel, Felix Schwarzhuber, Bernhard Zimmermann, Christian Back, and Josef Zweck — Universität Regensburg, Deutschland

Magnetic vortex oscillators are an ideal system to study the dynamics of magnetic systems at very small length scales and over a wide frequency range. Their dynamic behavior shows characteristics known from other fundamental physical systems like the harmonic oscillator and is in many aspects well understood. Here we present a study of coupled vortices with Lorentz Transmission Electron Microscopy (LTEM) and Differential Phase Contrast Microcopy (DPC) at zero magnetic field. We show a novel technique to control the interaction of two or more vortex oscillators by directly influencing their resonance frequencies. The resonance frequencies depend on the saturation magnetization M_s of the magnetic material, in this case permalloy and is highly dependent on the temperature. We use Joule heating to electrically manipulate the resonance frequencies and thus are able to control the coupling between two vortex oscillators. We systematically mapped the frequency response of both oscillators for different temperatures.

15 min. break

MA 48.8 Thu 11:30 HSZ 101

Spin-orbit torques in Chern insulators — •Jan-Philipp Hanke, Frank Freimuth, Stefan Blügel, and Yuriy Mokrousov — Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany

Spin-orbit torques (SOTs) arise as a result of an applied electric field in systems that combine broken spatial inversion symmetry and spin-orbit coupling. They allow for an efficient magnetization control in single ferromagnetic layers [1] mediated by the current-induced exchange of angular momentum between crystal lattice and magnetization. While previous works focused on SOTs in topologically trivial materials such as magnetic bilayers, the nature and magnitude of this phenomenon in insulators with globally nontrivial topology in reciprocal space was hardly addressed. Here, employing density functional theory and model calculations, we make contact with the field of Chern and topological insulators by investigating the SOT and Dzyaloshinskii-Moriya interaction (DMI) in a topologically complex system of magnetically-doped graphene. Both phenomena reveal unique fingerprints of the underlying topology, and we evaluate their interplay with the magnetization direction using higher-dimensional Wannier functions [2]. Remarkably, despite the absence of a longitudinal current, we predict that the magnitude of SOT and DMI in this family of Chern insulators is comparable to that observed in conventional magnetic metallic materials, which opens new vistas for dissipationless electric magnetization control.

[1] I. M. Miron *et al.*, Nature **476**, 189 (2011).
[2] J.-P. Hanke *et al.*, Phys. Rev. B **91**, 184413 (2015).

MA 48.9 Thu 11:45 HSZ 101

Phase control in magnetic oscillators — •Michael Vogel[1], Johannes Wild[1], Felix Schwarzhuber[1], Bernhard Zimmermann[1], Claudia Mewes[2], Tim Mewes[2], Josef Zweck[1], and Christian H. Back[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Germany — [2]MINT Center / Depeartment of Physics and Astronomy, University of Alabama, Tuscaloosa, AL, USA

Magnetic vortex oscillators coupled via their stray fields [K. Yu. Guslienko, et al. PRB 65, 024414 (2001)] are possible building blocks for high frequency logical networks with scalable dynamics and geometries. For information processing in such networks phase control is crucial. Here we present a novel technique to control the phase of two such oscillators by manipulating the saturation magnetization in one of them by Joule heating. This is demonstrated by high resolution, time resolved STXM measurements performed at the MAXYMUS beamline at Bessy II (Berlin, Germany).

MA 48.10 Thu 12:00 HSZ 101

Spin Hall magnetoresistance up to the THz regime: Signal magnification with spin-waves excitations — •Filipe Souza Mendes Guimarães[1], Manuel dos Santos Dias[1], Juba Bouaziz[1], Antonio Tavares da Costa[2], Roberto Bechara Muniz[2], and Samir Lounis[1] — [1]Peter Grünberg Institut and Institute for Advanced Simulation, Forschungszentrum Jülich and JARA, 52425 Jülich, Germany — [2]Universidade Federal Fluminense, Niterói, Brazil

Spin-orbit-related effects offer the utmost standard of reading and writing information in magnetic units for future devices. These phenomena rely not only on the static orientation of the magnetization but also on its dynamics to achieve fast switchings that can reach the Terahertz regime.[1] In this work, we demonstrate that dynamical charge and spin pumping mechanisms can greatly magnify or dwindle the currents flowing through the system, influencing all kinds of magnetoresistive effects and also Hall currents. In contrast to the static counter-parts, the dynamical signals can be modified by a few to hundreds percents, which leads to immediate implications for device concepts in the THz range. We show, in Co/Pt and Fe/W bilayers, that the variation on the amplitude of these ac-currents can reach up to two orders of magnitude and also affect dc and second harmonic signals. We further show that, by exploring the resonance of the system, dynamical spin Hall angles can non-trivially change sign and be significantly boosted by over 1000%, reaching giant values that are comparable to the dc ones obtained in high resistivity phase of Ta and W.
[1] F. S. M. Guimarães et al., Phys. Rev. B 92, 220410(R) (2015).

MA 48.11 Thu 12:15 HSZ 101

Negative differential conductance in atomic-scale nano-antiferromagnets — •Steffen Rolf-Pissarczyk[1,2], Shichao Yan[1,2], Luigi Malavolti[1,2], Jacob Burgess[1,2], Gregory McMurtrie[1,2], and Sebastian Loth[1,2,3] — [1]Max-Planck-Institut für Struktur und Dynamik der Materie, Hamburg, Germany — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart, Germany — [3]Institut für Funktionelle Materie und Quantentechnologien, Universität Stuttgart, Germany

Negative differential conductance (NDC) is a widely applied operation principle in modern electronic devices and it has been observed in different physical systems. The realization of a spin-based NDC effect especially in antiferromagnetic systems may enable new functionality. Here we report the manifestation of a spin-dependent NDC effect through an artificially constructed nano-antiferromagnet in the junction of a spin-polarized scanning tunneling microscope (SP-STM). The NDC occurs due to the occupation of a long-lived excited spin state of the nano-antiferromagnet which reduces the tunneling rate of the spin-polarized tunneling electrons. Applying a master rate equation method based on an effective spin-Hamiltonian provides detailed understanding of the underlying process. This NDC mechanism differs from those previously known as it uses substantially spin selection rather than energy selection in the transport channel.

MA 48.12 Thu 12:30 HSZ 101

Electrically detected magnetic vortex dynamics in Permalloy disks — •Lakshmi Ramasubramanian[1,2], Ciarán Fowley[1], Attila Kákay[1], Oguz Yildirim[1], Patrick Matthes[4], Jürgen Lindner[1], Jürgen Fassbender[3], Sibylle Gemming[1,2], Stefan E. Schulz[2,4], and Alina M. Deac[1] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [2]Technische Universität Chemnitz, 09126 Chemnitz, Germany — [3]Institute for Physics of Solids, TU Dresden, 01069 Dresden, Germany — [4]Fraunhofer Institute for Electronic Nano Systems, 09126 Chemnitz

The magnetic vortex is a potential candidate for future spintronic devices, like frequency sensors [S. Kasai, et al. PRL 97, 107204 (2006)]

[R. Moriya, et al. Nat. Phys. 4:368 (2008)], spin torque oscillators [V. S. Pribiag, et al. Nat. Phys. 3:498 (2007)], and tunable magnonic crystals [J. Shibata, et al. PRB 67, 224404 (2003)]. The fundamental frequency is determined by the saturation magnetisation, as well as the geometrical confinement of the magnetisation i.e. the diameter and height of a magnetic disk. In this study, Permalloy disks (with radii ranging from 500nm to 4000nm) are patterned and contacted to study the interaction of spin polarized current on the magnetic vortex. The presence of vortex is verified by magneto optic Kerr effect, X-ray photoemission electron microscopy and magnetotransport measurements. The resonance frequency is measured using a lock-in technique based on the anisotropic magnetoresistance effect. Modification of the resonance frequency by ion irradiation will be presented.

MA 48.13 Thu 12:45 HSZ 101

Quantum spin dynamics in a spin-1/2 antiferromagnetic Heisenberg-Ising chain — •Zhe Wang[1,2], Anup Kumar Bera[3], Nazmul Islam[3], Bella Lake[3], Joachim Deisenhofer[2], and Alois Loidl[2] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]University of Augsburg, Augsburg, Germany — [3]Helmholtz-Zentrum Berlin, Berlin, Germany

Emergent states of matter in quantum magnets are characterized by their elementary magnetic excitations that can be induced and tuned in an external magnetic field. We report on terahertz spectroscopy of elementary excitations in a spin-1/2 Heisenberg-Ising antiferromagnetic chain as a function of temperature and magnetic field. At zero field confined spinon excitations are observed below the Néel temperature [1]. Emergent ferminonic excitations are observed in a transverse magnetic field [2], when the confinement is suppressed and an order-disorder phase transition is induced. In the longitudinal fields, the high-energy string excitations are observed in addition to the low energy spin exciations. These experimental results are understood by comparison to precise calculation of dynamic structure factors by the method of infinite time evolving block decimation and using Bethe ansatz for the transverse and longitudinal fields, respectively.

In collaboration with Hans Engelkamp, Papori Gogoi, Dmytro Kamenskyi, Michael Schmidt, Nanlin Wang, Congjun Wu, Jianda Wu, Shenglong Xu, Wang Yang.

[1]Zhe Wang et al. Phys. Rev. B 91, 140404(R) (2015). [2]Zhe Wang et al. Phys. Rev. B 94, 125130 (2016).

MA 48.14 Thu 13:00 HSZ 101

Quasi-one dimensional spin chains and unconventional magnetic excitations in $YbAlO_3$ — •Stanislav Nikitin[1], Liusuo Wu[2], Leonid Vasylechko[3], and Andrey Podlesnyak[2] — [1]Max Planck Institute for Chemical Physics of Solids, Dresden, 01187, Germany — [2]Quantum Condensed Matter Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee 37831, USA — [3]Lviv Polytechnic National University, Lviv, 79000, Ukraine

The low-energy spin dynamics of Yb^{3+} in $YbAlO_3$ have been studied using inelastic neutron scattering. We observe that Yb^{3+} moments form weakly coupled spin chains running along the c-axis without any significant magnetic interactions within the ab plane. CEF effect leads to large splitting of the Yb^{3+} multiplet $J = \frac{7}{2}$ and the magnetic properties at low temperatures are always dominated by the lowest-energy doublet, which can be described as pseudo spin $S = \frac{1}{2}$, and the effective Lange g-factor. Excitation spectrum of $YbAlO_3$ above the ordering temperature $T_N = 0.9\ K$, precisely represents a gapless multispinon continuum as was predicted for a $S = \frac{1}{2}$ Heisenberg chain. Below T_N the gap $\Delta = 0.3$ meV appears and the spectrum splits into the single-particle mode and two-particle continuum. Of particular relevance for the present results are also our previous investigations of $YbFeO_3$. In this compound Yb^{3+} moments forms similar magnetic chains but magnetic excitations are highly modified by a strong Fe-Yb interaction. Our results represent a rather rare case of quantum spin dynamics in 4f based systems and provide an experimental basis for future studies of low-dimensional magnets.