MA 34: Spin Dynamics and Transport: Magnonics

Time: Wednesday 9:30–13:00 Location: HSZ 04

MA 34.1 Wed 9:30 HSZ 04

Direct Microscopic Observation of Spin Wave Focussing in a Fresnel Lens — •Joachim Gräfe[1], Martin Decker[2], Kahraman Keskinbora[1], Matthias Noske[1], Przemysław Gawronski[3], Hermann Stoll[1], Christian H. Back[2], Gisela Schütz[1], and Eberhard J. Goering[1] — [1]MPI für Intelligente Systeme, Stuttgart — [2]Universität Regensburg, Regensburg — [3]AGH University of Science and Technology, Krakau, Polen

Manipulation of spin waves has recently gained significant scientific interest. Structuring of a spin system on the length scale of the exchange and dipole interactions allows the engineering of spin wave properties. By scanning x-ray microscopy it is possible to image spin wave propagation with spatial and time resolution of about 25 nm and 45 ps with high magnetic contrast based on the XMCD effect. Using this technique we explore the focusing properties of an interference based Fresnel lens for spin waves. We observed a focal spot confined to less than 800 nm at a distance of more than 5 μm from the zone plate. The intensity is increased by more than 20% above the emission intensity. Thus, the lens is effectively overcompensating the damping during spin wave propagation. Furthermore, the focal spot can be moved easily by changing the applied magnetic bias field in the mT range. Thus, this type of spin wave lens can provide a flexible intense spin wave spot and an effective magnon source for different magnonic or spintronic devices.

MA 34.2 Wed 9:45 HSZ 04

Writing magnonic waveguides in FeAl with an nano-sized ion beam — •Julia Osten, Tobias Hula, Kai Wagner, Xiaomo Xu, Gregor Hlawacek, Rantej Bali, Kay Potzger, and Helmut Schultheiss — Institute of Ion Beam Physics and Material Research , HZDR, Dresden, Germany

Spin waves, the eigen-excitations of ferromagnets, are promising candidates for spin transport in lateral devices. $Fe_{60}Al_{40}$ films in the B2 phase are paramagnetic. Starting from a FeAl film in the paramagnetic phase the incident ions randomize the site occupancies and, thereby, transform it into the chemically disordered, ferromagnetic A2 phase.
The aim is to investigate spin wave propagation in this ferromagnetic material in free standing structures as well as in ferromagnetic structures embedded within a paramagnetic matrix. Using Helium-Ion microscopy we create spatially well defined ferromagnetic FeAl conduits for spin waves with resolution down to nm range. Two different ferromagnetic stripes were implanted in a microstructured paramagnetic FeAl. A freestanding 2 μm width stripe. And a stripe of the same width which was embedded in a wider paramagnetic FeAl stripe. For the excitation of spin waves we processed a microwave antenna on top of these stripes. To detect spin waves we employed Brillouin light scattering microscopy. We show that the spin wave spectra are influenced by the surrounding paramagnetic material due to a different internal field distribution. The authors acknowledge financial support from the Deutsche Forschungsgemeinschaft within programme SCHU 2922/1-1.

MA 34.3 Wed 10:00 HSZ 04

Spin-Wave Mode Conversion via Optically Induced Landscapes of the Saturation Magnetization — •Marc Vogel[1], Rick Assmann[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

Magnons - eigen excitations of the electrons' spin system - are seen as a potential candidate for future data processing. For this, in-plane magnetized samples are the first choice because they do not require a large biasing field. However, due to a strong spin-wave anisotropy the backward volume magnetostatic spin waves (BVMSW) propagating along the biasing field and the magnetostatic surface spin waves (MSSW), propagating perpendicularly, exist in different frequency ranges.

Here, we use our recently reported technique of laser modified magnetic media [Nature Physics 11, 487 (2015)] to realize a highly efficient method to convert BVMSW to MSSW. Computer generated holograms are used to heat up the sample locally (due to the optical absorption). A temperature gradient evolves inside the waveguide resulting in a shift of the dispersion relations to lower frequencies. Thus, MSSW- and BVMSW-bands are formed. Both intersect with each other leading to the BVMSW-MSSW-mode conversion.

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

MA 34.4 Wed 10:15 HSZ 04

Snell's law for spin waves in a temperature gradient — •Michael Vogel, Johannes Stigloher, Martin Decker, and Christian H. Back — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Regensburg, Germany

Snell's law [J. W. Shirley. Am. J. Phys. 19, 507 (1951)] describes the relationship between incidencent and refracted parts of a wave in media with different group velocities by following Fermat's principle of least time. It is mainly prominent in optics, but due to only being based upon a translational symmetry argument applicable to many phenomena such as spin waves [J. Stigloher et al. PRL. 117, 037204 (2016)]. The dispersion relation for spin waves depends on the saturation magnetization which depends itself on temperature [7]. Here the transition of spin wave through a locally heated Permalloy film is studied by time resolved MOKE measurements. We show the possibility of changing the direction of spin waves by local manipulation of the temperature landscape.

MA 34.5 Wed 10:30 HSZ 04

Broadband spin-wave spectroscopy (BSWS) and micro-focused Brillouin Light Scattering (μBLS) on a nanostructured ferrimagnetic thin film — •Stefan Mändl[1], Ioannis Stasinopoulos[1], and Dirk Grundler[2] — [1]Physik Department E10, TU München, Garching, Germany — [2]Institut des Matériaux, École Polytechnique Fédérale de Lausanne, Lausanne, Switzerland

Magnonics is a growing research field where one aims at controlling spin waves on the nanoscale. Microwave-to-magnon transducers are in particular important for coupling magnonic devices to conventional microwave circuits. In 20 nm thick yttrium iron garnet (YIG) it was found that the reciprocal-lattice vector provided by a periodic array of Py nanodisks added to the wave vector of a Damon-Eshbach mode [1]. We study the effect in thick YIG of 200 nm by broadband spin-wave spectroscopy and micro-focused Brillouin Light Scattering. Two-dimensional lattices of different geometries are prepared with Electron Beam Lithography and Evaporation of Py. We find varying spin-wave decay lengths for different geometries and resolve spin-waves with wavelength down to 100 nm. The work is supported by the DFG via GR1640/5 in SPP 1538 and NIM.

[1] H. Yu et al., Nat. Commun. 7, 11255 (2016)

MA 34.6 Wed 10:45 HSZ 04

Frequency modulation of backward volume spin wave by electric current — •Nana Nishida[1], Seo-Won Lee[2], Seung-Jae Lee[3], Kyung-Jin Lee[2,3], Helmut Schultheiss[1], and Koji Sekiguchi[4,5] — [1]Helmholtz-Zentrum Dresden-Rossendorf, Dresden, Germany — [2]Department of Materials Science and Engineering, Korea University, Seoul, Korea — [3]KU-KIST Graduated School of Converging Science and Technology, Korea University, Seoul, Korea — [4]Department of Physics, Keio University, Yokohama, Japan — [5]JST-PRESTO, Tokyo, Japan

In the field of magnonics, spin waves are envisioned as a new candidate for information transport and processing. Since spin waves propagate without any charge displacement and are free from Joule heating, they offer significant reduction of energy consumption in devices. The spin transfer torque (STT) effect originating from conduction electrons is a powerful method for modulating spin waves. Here, we investigated the current induced Doppler shift of backward volume spin waves.

We fabricated a NiFe stripe with a width of 2 μm, which was magnetized in backward volume configuration. The antennas fabricated on top of the NiFe stripe were connected to a vector network analyzer for measuring the spin-wave spectra. We applied a dc current to the NiFe stripe. For a current density of 5×10^{10} A/m^2 the spin-wave frequencies shifted +170 MHz compared to the spin-wave spectra without dc current. This frequency shift is 60 times larger than previous works reported for forward volume spin waves. Hence, we demonstrated giant frequency modulation of backward volume spin waves by a dc current.

15 min. break

MA 34.7 Wed 11:15 HSZ 04

Curvature-Induced Asymmetry of Spin-Wave Dispersion — Jorge A. Otálora[1], Ming Yan[2], Helmut Schultheiss[3], Jürgen Lindner[3], Jürgen Fassbender[3], Riccardo Hertel[4], and •Attila Kákay[3] — [1]Universidad Técnica Federico Santa María, Avenida España 1680, Casilla 110-V, Valparaíso, Chile — [2]Shanghai University, 99 Shangda Road, Shanghai 200444, China — [3]HZDR, Institute of Ion Beam Physics and Materials Research, Bautzner Landstraße 400, 01328 Dresden, Germany — [4]IPCMS, UMR 7504, CNRS, and Université de Strasbourg, 23 rue du Loess, F-67034 Strasbourg, France

We show using micromagnetic simulations and analytical calculations that spin-wave propagation in ferromagnetic nanotubes is fundamentally different than in flat thin films. The dispersion relation is asymmetric regarding the sign of the wave vector. This is a purely curvature-induced effect and its fundamental origin is identified to be the classical dipole-dipole interaction. In certain cases the Damon-Eshbach modes in nanotubes behave as the volume-charge-free backward volume modes in flat thin films. Such non-reciprocal spin-wave propagation [1] is known for flat thin films with Dzyalonshiinsky-Moriya interaction (DMI), an antisymmetric exchange due to spin-orbit coupling. The analytical expression of the dispersion relation has the same mathematical form as in flat thin films with DMI. The influence of curvature on spin waves is thus equivalent to an effective dipole-induced Dzyalonshiinsky-Moriya interaction [2]. [1] K. Zakeri, et. al., Phys. Rev. Lett. **104**, 137203 (2010). [2] J.A. Otálora, et. al., Phys. Rev. Lett. **117**, 227203 (2016).

MA 34.8 Wed 11:30 HSZ 04

Anderson Localization in antiferromagnets: comparing length and time scales to ferromagnets — •Martin Evers, Coralie Schneider, Cord A. Müller, and Ulrich Nowak — University of Konstanz, D-78457 Konstanz

As Anderson showed in 1958, in case of phase coherent transport disorder can lead to completely suppressed transport, a phenomenon known as Anderson localization [1]. For the case of spin waves this will lead to a limited propagation, even without any dissipative damping mechanism [2,3].

In the field of spin transport there is a growing interest in antiferromagnets and other materials with multiple magnetic sublattices. We investigate numerically magnonic transport with respect to Anderson localization in one and two dimensional antiferromagnets. The relevant time and length scales of weak and strong localization are compared to ferromagnets. We find clear differences, especially a much shorter localization length in antiferromagnets.

[1] P. W. Anderson, Phys. Rev. **109**, 1492 (1958)
[2] U. Ritzmann et al., Phys. Rev. B **89**, 024409 (2014)
[3] M. Evers et al., Phys. Rev. B **92**, 014411 (2015)

MA 34.9 Wed 11:45 HSZ 04

Unidirectional short-wavelength spin wave propagation using one-dimensional nanogratings — •Tobias Stückler[1], Jilei Chen[1], Houchen Chang[2], Chuanpu Liu[3], Tao Liu[2], Junfeng Hu[1], Zhe He[1], Weisheng Zhao[1], Zhimin Liao[3], Dapeng Yu[3], Mingzhong Wu[2], and Haiming Yu[1] — [1]Fert Beijing Research Institute, School of electronic and information engineering, Beihang University, Beijing, China — [2]Department of Physics, Colorado State University, Fort Colins, CO, United States — [3]State Key Laboratory for Mesoscopic Physics and Electron Microscopy Laboratory, School of Physics, Peking University, Beijing, China

Utilization of spin waves for information processing has recently seen rapid development. [1] We report spin wave propagation in 1D magnonic nanograting coupler. [2] Nanograting coupler (GC) signals are enhanced compared with conventional antennas which make them a powerful tool for spin wave modulation. Our samples consist of periodic Nickel nanowires grown on nm-thick YIG films with very low Gilbert damping. [3] We use coplanar wave guides to excite and vector network analyzer to detect our signal. Compared to 2D NC [4], we find that 1D NC provoke unidirectional short-wavelength spin waves propagating along the YIG micro-channel and avoid energy losses. References: [1] A. V. Chumak, V. I. Vasyuchka, A. A. Serga, et al, Nature Physics, 11(6), 453-461 (2015). [2] H. Yu, O. A. Kelly, V. Cros, et al, Scientific reports, 4, 6848 (2014). [3] H. Chang, P. Li, W. Zhang, et al, Magnetics Letters, IEEE, 5, 1-4 (2014). [4] H. Yu, G. Duerr, R. Huber, et al, Nature communications, 4, 2702 (2013).

MA 34.10 Wed 12:00 HSZ 04

Interatomic Exchange Interactions for Finite-Temperature Magnetism and Nonequilibrium Spin Dynamics — •Attila Szilva[1], Marcio Costa[1,2,3], Anders Bergman[1], Laszlo Szunyogh[4], Lars Nordström[1], and Olle Eriksson[1] — [1]Department of Physics and Astronomy, Division of Materials Theory, Uppsala University, Box 516, SE-75120 Uppsala, Sweden — [2]Instituto de Fisica, Universidade Federal Fluminense, 24210-346 Niteroi, Rio de Janeiro, Brazil — [3]Department of Physics and Astronomy, University of California, Irvine, California 92697, USA — [4]Department of Theoretical Physics and Condensed Matter Research Group of Hungarian Academy of Sciences, Budapest University of Technology and Economics, Budafoki ut 8., H1111 Budapest, Hungary

We derive ab inito exchange parameters for general noncollinear magnetic configurations, in terms of a multiple scattering formalism. We show that the general exchange formula has an anisotropiclike term even in the absence of spin-orbit coupling, and that this term is large, for instance, for collinear configuration in bcc Fe, whereas for fcc Ni it is quite small. We demonstrate that keeping this term leads to what one should consider a biquadratic effective spin Hamiltonian even in the case of collinear arrangement. To illustrate our results in practice, we calculate for bcc Fe magnon spectra obtained from configuration-dependent exchange parameters, where the configurations are determined by finite-temperature effects. Our theory results in the same quantitative results as the finite-temperature neutron scattering experiments.

MA 34.11 Wed 12:15 HSZ 04

Domain configuration mediated spinwave superpositions — •Rasmus B. Holländer, Cai Müller, Mathis Lohmann, and Jeffrey McCord — Institute for Materials Science, Kiel University, Kaiserstraße 2, 24143 Kiel, Germany

Spin waves can be generated in close proximity to domain walls [1] or at vortex core centers [2]. Here, we employ time-resolved magneto-optical wide-field imaging in an enhanced concept to directly monitor the local magnetization vector response to an external stimulus in the time domain. Variation of the azimuthal angle of incidence of the probing light yields differential magnetic vector information of the integral signal, allowing for separation of polar and pure in-plane Kerr components. A ferromagnetic resonance geometry utilizing the quasi-homogeneous Oersted-field on top of a coplanar waveguide is used as an excitation scheme. The magneto-dynamic response of an amorphous CoFeB stripe element is investigated in several magnetic domain configurations exhibiting asymetric Bloch walls. The data obtained from different sensitivity directions indicate superpositions of spin waves with wavefronts parallel to the domain walls in a configuration similar to the Damon-Eshbach mode.

The authors thank the German Science Foundation (DFG) for the financial support (grant Mc9/9-2 and Mc9/10-2).

[1] B. Mozooni and J. McCord, APL 107, 042402 (2015)
[2] S. Wintz et al., Nature Nanotech. 11, 948 (2016)

MA 34.12 Wed 12:30 HSZ 04

Electrically Driven Bose-Einstein Condensation of Magnons in Antiferromagnets — Eirik Fjaerbu, •Niklas Rohling, and Arne Brataas — Department of Physics, Norwegian University of Science and Technology, NO-7491, Trondheim, Norway

We explore routes to realize electrically driven Bose-Einstein condensation of magnons in insulating antiferromagnets. Even in insulating antiferromagnets, the localized spins can strongly couple to itinerant spins in adjacent metals via spin-transfer torque and spin pumping [1]. Our model describes a system where a spin accumulation in an adjacent normal metal is aligned with the staggered field of the antiferromagnet. This spin accumulation controls the formation of steady-state magnon condensates. Compared to the earlier proposed ferromagnetic case [2,3], there are two significant differences for antiferromagnets: Firstly, two types of magnons exist in antiferromagnets, which carry opposite magnetic moments. Consequently, Bose-Einstein condensation can occur for either sign of the spin accumulation. Secondly, in antiferromagnets, the operating frequencies of the condensate are orders of magnitude faster than in ferromagnets.

[1] R. Cheng, J. Xiao, Q. Niu, and A. Brataas, Phys. Rev. Lett. **113**, 057601 (2014)
[2] S. A. Bender, R. A. Duine, and Ya. Tserkovnyak, Phys. Rev. Lett. **108**, 246601 (2012)
[3] S. A. Bender, R. A. Duine, A. Brataas, and Ya. Tserkovnyak,

Phys. Rev. B **90**, 094409 (2014)

MA 34.13 Wed 12:45 HSZ 04

Femtosecond quantum spin dynamics induced by femto-nanomagnons in Heisenberg antiferromagnets — •Olena Gomonay[1], Davide Bossini[2], Johan Metnik[3], and Jairo Sinova[1] — [1]Institut für Physik, Johannes Gutenberg Universität Mainz, D-55099 Mainz, Germany — [2]University of Tokyo, Japan — [3]Radboud University Nijmegen, Nijmegen, The Netherlands

The major interest of spintronics has recently directed to antiferromagnets which could allow high density storage in a memory device and high frequencies of data processing entering the THz regime.

The use of all-optical schemes opens a way towards the ultrafast manipulation of an antiferromagnets, which up to now was restricted to low-energy magnons at the center of the Brillouin zone. Here we focus on the impulsively generated coherent magnons with the wavevector near the edges of the Brillouin zone – femto-nanomagnons.

We investigate the macrospin dynamics induced by femto-nanomagnons and propose a simple quantum mechanical description of the two-magnon excitation mechanism, based on a light-induced modification of the exchange. We demonstrate that femto-nanomagnonics dynamical regime has purely quantum mechanical nature and that the dynamics is exclusively longitudinal. A complete description of the squeezed-states induced by the femto-nanomagnons is also reported. We also formulate an effective phenomenological theory of the femtosecond longitudinal spin dynamics. We believe that our results pave a way to manipulation and control of squeezed states in the magnetic systems.