MA 43: Magnetization Dynamics III

Time: Thursday 15:00–18:15 Location: HSZ 401

MA 43.1 Thu 15:00 HSZ 401

Magneto-elastic modes and magnon lifetime in thin yttrium-iron garnet films — •Andreas Rückriegel[1,2] and Peter Kopietz[1,2] — [1]Institut für Theoretische Physik, Universität Frankfurt — [2]Department of Physics, University of Florida

We calculate the effect of the spin-lattice coupling on the magnon spectrum of thin films of the magnetic insulator yttrium-iron garnet. We show that the hybridisation between phonons and magnons generates characteristic phonon peaks in the magnon spectral function and give explicit expressions for the spectral weight of these peaks. We also derive the interaction vertices between magnons and phonons and estimate the resulting phonon contribution to the magnon life-time at room temperature.

MA 43.2 Thu 15:15 HSZ 401

Spin Dephasing and Magnetization Damping due to electron-phonon scattering in a ferrimagnetic s-d model — Alexander Baral and •Hans-Christian Schneider — University of Kaiserslautern and Research Center OPTIMAS

We calculate the spin dynamics in a model of itinerant carriers coupled antiferromagnetically to a macrospin ("ferrimagnetic s-d model") due to the coupling to a phonon bath in the presence of spin-orbit coupling. Using a mean-field approximation for the s-d model, we derive Boltzmann scattering integrals for the distributions and spin coherences for the case of a antiferromagnetic exchange splitting, which is complicated by dynamical changes of the longitudinal and transversal magnetization directions. We assume the spin-orbit coupling to be of the Rashba form so that the resulting model describes a form of Elliot-Yafet type electron-phonon scattering within an equation of motion formalism. We extrapolate dephasing- and magnetization times and draw a comparison to phenomenological equations such as Landau-Lifshitz (LL) [1] or Landau-Lifshitz-Gilbert (LLG) [2]. We then analyze the magnetization precession and relaxation of the antiferromagnetically coupled carrier spins and macrospin in an anisotropy field [3] and find a carrier mediated dephasing of the macrospin via mean-field coupling.

[1] L. D. Landau and E. M. Lifshitz, Phys. Z. Sowjet., vol. 8, pp. 153-169 (1935).

[2] T. L. Gilbert, IEEE Transactions on Magnetics, vol. 40(6), pp. 3443-3449 (2004).

[3] Y.Tserkovnyak, Applied Phys. Lett Vol.84, Number 25 (2004).

MA 43.3 Thu 15:30 HSZ 401

Nonlinear spin-wave scattering in a micro-structured magnonic crystal — Björn Obry[1], •Thomas Meyer[1], Philipp Pirro[1], Thomas Brächer[1,2], Julia Osten[3], Andrii V. Chumak[1], Alexander A. Serga[1], Jürgen Fassbender[3], and Burkard Hillebrands[1] — [1]FB Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Graduate School Materials Science in Mainz, 67663 Kaiserslautern, Germany — [3]Institut für Ionenstrahlphysik und Materialforschung, Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany, and TU Dresden, 01062 Dresden, Germany

We study the nonlinear multi-magnon processes in a micro-structured magnonic crystal consisting of a $Ni_{81}Fe_{19}$ waveguide, which has been periodically modulated in its saturation magnetization by localized ion implantation. A significant modification of the nonlinear magnon spectrum compared to a reference waveguide is determined, exhibiting a predominant scattering into modes with a frequency at the magnonic band gaps and an enhancement of the nonlinearities for some excitation frequencies. The results prove the feasibility to utilize nonlinear multi-magnon scattering for magnon spintronic applications on the micrometer scale.

MA 43.4 Thu 15:45 HSZ 401

Spin wave mediated synchronization of localized modes in spin torque nano-oscillators — •Thomas Kendziorczyk and Tilmann Kuhn — Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster

Spin torque nano-oscillators (STNOs) are promising candidates for tunable nanoscale microwave sources for applications in chip-to-chip and wireless communications. In 2005 it has been demonstrated experimentally [1], that two STNOs can be synchronized, which can greatly increase their output power. The synchronization of the STNO pair was realized by mutual interaction through propagating spin waves. However this experiment has been performed for an out-of-plane magnetized magnetic film, which requires impractical high external magnetic fields. In this contribution we will show by means of micromagnetic modeling how to achieve long-range synchronization between STNOs which are placed on an in-plane magnetized magnetic film. While requiring much lower external fields, usually the excited modes for STNOs in this geometry are self-localized. However, it is possible through the local modification of the internal field to increase the frequency of the STNO above the FMR of the surrounding film, which promotes emission of spin waves [2]. We predict, that two such localized modes which are coupled by spin waves in the surrounding material can be used for a long-range synchronization through the emission of directional spin waves.

1. S. Kaka et al., Nature 437, 389 (2005)
2. H. Ulrichs et al., Appl. Phys. Lett. 100,16 (2012)

MA 43.5 Thu 16:00 HSZ 401

Spin waves in ultrathin hexagonal Cobalt films — •Eugen Michel[1,2], Jayaraman Rajeswari[1,2], Harald Ibach[1,2], and Claus M. Schneider[1,2] — [1]Peter-Grünberg-Institut, Forschungszentrum Jülich, 52425 Jülich, Germany — [2]Jülich Aachen Research Alliance, Germany

As previous publications [1,2] have shown electron energy loss spectroscopy is a promising tool for studies of large wave vector spin waves in the surface and thin film region. Using our high-resolution spectrometer [3] we have probed the dispersion of spin waves in hexagonal Co-films grown on Cu(111) and Au(111) single crystal surfaces. The film thicknesses ranged from 3 to 18 atomic layers (AL). For Co grown on Cu(111) we have observed surface spin wave signatures with wave vectors in the range of q = 2 - 8 1/nm. Furthermore we have resolved standing wave modes for film thicknesses between 3AL and 5AL. The results are compared to theoretical calculations based on the Heisenberg model with adjusted exchange coupling constants. The spin wave spectra from films grown on Au(111) exhibit a significant broadening, which is attributed to the higher disorder of the Co-films. The spectra can be simulated taking the experimentally determined wave vector resolution into account.

[1] R. Vollmer et al., JMMM 272-276, (3), pp 2126-2130 (2004).

[2] J. Rajeswari et al., Phys. Rev. B 86, 165436 (2012).

[3] H. Ibach et al., JESRP 185, 3 - 4, pp 61-70 (2012).

MA 43.6 Thu 16:15 HSZ 401

Standing spin waves in thin magnetic films: A method to test for layer-dependent exchange coupling — •Jayaraman Rajeswari, Harald Ibach, and Claus M. Schneider — Peter Grünberg Institut, Forschungszentrum Jülich, 52425 Jülich, Germany

We present an experimental method for probing the layer dependence of exchange coupling constants in thin magnetic films. The method is based on the simultaneous observation of standing spin waves with a single node inside the film and surface spin waves of the film using the technique of inelastic electron scattering. Experimental data are shown for 5-8 layers of fcc cobalt deposited on Cu(100). The data are compared to theoretical studies predicting a strong enhancement of the exchange coupling constants at the surface and the interface and even oscillations near surface and interface. Neither one fits the experimental data per se, while a simple nearest neighbor Heisenberg model with uniform exchange coupling does. We therefore conclude a small depth dependence of the exchange coupling between atoms.

15 min. break

MA 43.7 Thu 16:45 HSZ 401

Condensation of mixed magnon-phonon states below the bottom of the magnon spectrum — •Dmytro A. Bozhko[1], Alexander A. Serga[1], Peter Clausen[1], Vitaliy I. Vasyuchka[1], Andrii V. Chumak[1], Gennadii A. Melkov[2], and Burkard Hillebrands[1] — [1]Fachbereich Physik and Landesforschungszentrum OPTIMAS, TU Kaiserslautern, Germany — [2]Faculty of Radiophysics, Taras Shevchenko National University of Kyiv, Ukraine

The Brillouin light scattering technique is used to measure the distribution of a parametrically driven magnon gas in frequency and wavevector spaces. The experiment is performed utilizing an in-plane magnetized 6.7 μm thick single-crystal yttrium iron garnet film. A magnetizing field is tuned to excite the parametric magnons at the ferromagnetic resonance frequency of 6.8 GHz. In the case of a quasi-uniform pumping field, we are able to detect a strong magnon density peak around the bottom of the spin waves spectrum (4.8 GHz) at the hybridization area ($8 \cdot 10^4$ rad/cm) between a backward volume magnetostatic wave and a transverse acoustic wave. This peak is understood as the condensation of magnon-phonon quasi-particles at a virtual energy minimum, whose frequency position is determined by magnon-phonon interaction. It is remarkable that no condensation is observed in the spatially localized pumping field: The magnon-phonon quasi-particles have a very high group velocity, and thus leave the thermalization area. Financial support by the DFG within the SFB/TR 49 is gratefully acknowledged.

MA 43.8 Thu 17:00 HSZ 401

Thermalization and Bose-Einstein condensation of magnons — •Julian Hüser and Tilmann Kuhn — Institut für Festkörpertheorie, Westfälische Wilhelms-Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster

In 2006 Demokritov and co-workers observed clear evidence for room temperature Bose-Einstein condensation of magnons [1]. The BEC threshold was reached by increasing the magnon density by means of parametric pumping. The pumped magnons quickly redistributed over the spin wave spectrum and a macroscopic fraction finally accommodated the dispersion minimum leading to Bose-Einstein condensation.

Nevertheless, from the theoretical point of view the role of the different types of interaction processes among the magnons themselves and between magnons and phonons are still not well understood.

In this work we analyze the nonequilibrium dynamics of the hot magnon gas and the time evolution of the condensate by solving the quantum Boltzmann equation. We investigate the various types of interaction between magnons and phonons which can be grouped into two classes. The first type leads to a relaxation of the magnetic system whereas the second type keeps the magnon number constant thus only leading to an energy relaxation. We show that the latter interaction even enhances the condensate under certain conditions.

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[1] S. O. Demokritov, V. Demidov, O. Dzyapko, G. A. Melkov, A. A. Serga, B. Hillebrands, and A. N. Slavin, Nature 443, 430 (2006)

MA 43.9 Thu 17:15 HSZ 401

Time-resolved imaging of isolated confined spin-wave packets — •Philipp Wessels[1], Marek Wieland[1], Jan-Niklas Tödt[2], and Markus Drescher[1] — [1]Institute for Experimental Physics, University of Hamburg, Germany — [2]Institute of Applied Physics, University of Hamburg, Germany

We present spatially and temporally resolved measurements on the dynamics of isolated spin-wave packets created by a short, broadband current pulse. The time evolution of the magnetization in confined magnetic media is analyzed by a time-resolved scanning Kerr microscope (TR-SKM) via the magneto-optic Kerr effect (MOKE) in combination with femtosecond laser pulses to carry out stroboscopic pump-probe experiments.

With a novel pump approach utilizing a magnesium photocathode as electro-optical switch, the generation of intense electronic current pulses becomes possible for excitation of magnetic systems with the transported transient magnetic field. The available master laser pulses of 1030 nm wavelength and 290 fs duration are doubled in frequency to obtain probe pulses of 515 nm wavelength which are further converted into UV pump pulses of 258 nm wavelength by another frequency doubling stage to drive the photocathode.

This enables jitter-free measurements on isolated spin-wave packets in permalloy ($Ni_{80}Fe_{20}$) microstructures with a temporal resolution $<$ 10 ps and a spatial resolution $<$ 670 nm FWHM. The spatially and temporally resolved data set permits a direct observation and global analysis of the dynamic parameters defining the wave-packet.

MA 43.10 Thu 17:30 HSZ 401

Material engineering for all-optical switching — •Ute Bierbrauer[1], Stéphane Mangin[2,3], Matthias Gottwald[3], Charles-Henri Lambert[2,3], Daniel Steil[1], Vojtech Uhlíř[3], Lin Pang[4], Michel Hehn[2], Sabine Alebrand[1], Mirko Cinchetti[1], Stefan Mathias[1], Grégory Malinowski[2,5], Yeshaiahu Fainman[4], Eric E. Fullerton[3,4], and Martin Aeschlimann[1] — [1]University of Kaiserslautern, Germany — [2]Institute Jean Lamour, Université de Lorraine, France — [3]Center for Magnetic Recording Research, San Diego, USA — [4]University of California San Diego, USA — [5]Laboratoire de Physique des Solides, Université Paris-Sud, France

Since the discovery of all-optical switching (AOS) in ferrimagnetic rare-earth transition metal (RE-TM) alloy films [1,2] the question arose if a manipulation of magnetic order without applying magnetic fields is also possible in engineered ferrimagnetic materials without rare-earth-elements.

Here we demonstrate that AOS can also be observed in more complex systems, including multilayer structures and synthetic ferrimagnetic hetero-structures. Furthermore we show the magnetization dynamics of these materials, particularly with a closer view on the magnetization reversal occurring on the ultrafast timescale. The presented results open a new pathway to engineering materials for future applications based on all-optical control of magnetic order and show new insights about the phenomenon of AOS.

[1] C.D. Stanciu et al., PRL 99, 047601 (2007)
[2] S. Alebrand et al., APL 101, 162408 (2012)

MA 43.11 Thu 17:45 HSZ 401

Magnetic linear dichroism in resonant photoemission of Co thin films — •Torsten Veltum[1], Tobias Löffler[1], Sven Döring[2], Lukasz Plucinski[2], and Mathias Getzlaff[1] — [1]Institut für Angewandte Physik, Heinrich-Heine-Universität Düsseldorf, 40225 Düsseldorf — [2]Peter Grünberg Institut PGI-6, Forschungszentrum Jülich, 52428 Jülich

Magnetic linear dichroism in the angular distribution of photoelectrons (MLDAD) is a technique that allows the study of both the electronic band structure and the magnetic properties of thin films and single crystals. We are looking for a deeper understanding of the magnetic linear dichroism of 3d metals, specifically which parts of the band structure are responsible for this phenomenon. In this study linearly polarized synchrotron radiation (Beamline 5, DELTA Dortmund) in the VUV regime is used. The studied system is an epitaxially grown hcp(0001) Co thin film on a W(110) surface.
The electronic structure of the valence band is measured by variation of the photon energy. At lower energies, dichroism measurements are confirmed [1] and extended to angle-resolved spectra in off-normal geometry. These angle-resolved measurements present opposite effects for positive and negative detection angles. At 60 eV photon energy we observe a resonance between the Co 3p and the valence band which influences the dichroism.

[1] J. Bansmann et al., Surf. Sci. 454-456 (2000), 686-691

MA 43.12 Thu 18:00 HSZ 401

A sensor layer to magnify the magnetic vortex core polarization — •Georg Dieterle[1], Joachim Gräfe[1], Matthias Noske[1], Markus Sproll[1], Ajay Gangwar[1,2], Markus Weigand[1], Hermann Stoll[1], Georg Woltersdorf[2], Christian H. Back[2], and Gisela Schütz[1] — [1]MPI for Intelligent Systems, Stuttgart, Germany — [2]Department of Physics, Regensburg University, Germany

Sophisticated techniques like synchrotron based X-ray microscopy have to be used for imaging the vortex core (which can point either up or down) in magnetic vortex structures. We show how to magnify the vortex core magnetization to a diameter in the micrometer range in order to detect its polarization with magneto-optical Kerr effect (MOKE) microscopy. This can be achieved by a GdFe multilayer with out-of-plane magnetization and very low coercivity on top of a Permalloy vortex structure. The vortex core in the Permalloy disc is switched unidirectionally by a rotating RF magnetic field burst at the gyromode frequency of the vortex structure (about 570 MHz in our samples) with an amplitude A and a duration L. The reversal of the vortex core polarization by this RF burst also causes a defined reversal of the out-of-plane magnetization of the whole GdFe layer, 500 nm in diameter, which now can be easily detected by MOKE microscopy. Therefore, the GdFe layer acts as a sensor layer to magnify the polarization of the tiny vortex core. Experimental data are reported on the amplitude A and the duration L of the rotating RF fields necessary to switch both, (i) the vortex core polarization in the Permalloy disc and (ii) the magnetization of the whole GdFe disc above the vortex structure.