MA 36: Magnetization and Demagnetization Dynamics III

Time: Wednesday 15:00–18:15 Location: H34

MA 36.1 Wed 15:00 H34

Influence of magneto-elastic coupling in magnetization dynamics — •Matthias Assmann and Ulrich Nowak — University Konstanz, 78457 Konstanz, Germany

For modern nanoscale devices a profound understanding of the atomistic interactions is crucial. Modern experiments have access to magnetization dynamics on femtosecond timescale as well as to phononic excitations. We developed therefore a model, which allows a coupling between these two thermodynamic sub-systems under strict observance of energy and angular momentum conservation laws. For this model we perform spin-molecular dynamics simulations, which take into account the spatial as well as the spin degrees of freedom. This coupling between the spin and lattice degrees of freedom is achieved by pseudo dipolar forces. These coupling contributes to various effects like damping, domain wall movement and magneto-volume effects.

MA 36.2 Wed 15:15 H34

Magnetization dynamics driven by surface acoustic waves — Eric R. J. Edwards, •Rouven A. Dreyer, Niklas Liebing, and Georg Woltersdorf — Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Halle (Saale), Deutschland

We use surface acoustic waves (SAW) to excite magnetization dynamics magneto-elastically in magnetic film and elements. Here we present a detailed experimental analysis of SAW driven ferromagnetic resonance in Nickel elements with different sizes as function of the external magnetic field amplitude, magnetic field orientation and SAW frequency (and wave vector). In the experiments the surface acoustic waves are excited at the surface of LiNbO3 substrates using lithographically patterned interdigital transducers (IDT). At the same time the induced magnetization dynamic is probed locally by time-resolved Kerr microscopy. The frequency (and wave vector) dependence of the SAW driven FMR is measured, using odd harmonics of the IDT fundamental frequency. The experimental results are described by a model based on the magneto-elastic coupling.

MA 36.3 Wed 15:30 H34

Relevance of the exchange coupling in ultrafast demagnetization of ferromagnetic alloys — •Stefan Günther[1,12], Carlo Spezzani[2,11], Roberta Ciprian[3], Cesare Grazioli[2,4], Barbara Ressel[4], Marcello Coreno[2,5], Luca Poletto[6], Paolo Miotti[6], Maurizio Sacchi[7,8,9], Giancarlo Panaccione[3], Vojtěch Uhlíř[10], Eric E. Fullerton[10], Giovanni De Ninno[2,4], Christian H. Back[1], and Manfred Fiebig[12] — [1]University of Regensburg — [2]Elettra Sincrotrone Trieste — [3]IOM-CNR, Triest — [4]University of Nova Gorica — [5]CNR-IMIP, Rome — [6]CNR-IFN, Padova — [7]Sorbonne Universités, Paris — [8]Centre national de la recherche scientifique, Paris — [9]Synchrotron SOLEIL, Saint-Aubin — [10]University of California, San Diego — [11]University Paris Sud — [12]ETH Zürich

We use element-resolved infrared-pump/extreme ultraviolet-probe experiments to disentangle the ultrafast interplay of magnetic alloys during ultrafast demagnetization. As paradigmatic examples, we investigate the cases of the FeRh alloy (crystalline and ordered), FeCo alloy (crystalline but disordered) and FeNi alloy (polycrystalline). All three systems reveal different dynamics for the alloy's components and a distinct time difference in the onset of the demagnetization is observed. The magnitude of this temporal delay is related to the interatomic exchange interaction for all three systems where the mismatch of the demagnetization traces decreases with stronger coupling.

MA 36.4 Wed 15:45 H34

Ultrafast magnetization dynamics in amorphous FeGd alloys — •Raghuveer Chimata — Department of Physics and Astronomy, Uppsala University, Box-516 Uppsala

In recent years, there has been an intense interest in understanding the microscopic mechanism of thermally induced magnetization switching driven by a femtosecond(fs) laser pulse. Most of the efforts have been dedicated to periodic crystalline structures while the amorphous counterparts have been less studied. By using a multiscale approach, i.e. first-principles density functional theory combined with atomistic spin dynamics, we report here on the very intricate structural and magnetic nature of amorphous Gd-Fe alloys for a wide range of Gd and Fe atomic concentrations at the nanoscale level. Both structural and dynamical properties of Gd-Fe alloys reported in this work are in good agreement with previous experiments. We calculated the dynamic behavior of homogeneous and inhomogeneous amorphous Gd-Fe alloys and their response under the influence of a fs laser pulse. In the homogeneous sample, the Fe sublattice switches its magnetization before the Gd one. However the switching process is reversed in the inhomogeneous sample. Furthermore, our results point out that a microscopic mechanism for all-thermal switching does not need to involve spin current effects.

MA 36.5 Wed 16:00 H34

Ultrafast and energy-efficient spin manipulation: Antiferromagnetism beats Ferromagnetism — •Nele Thielemann-Kühn[1,2], Daniel Schick[1], Niko Pontius[1], Christoph Trabant[1,2,3], Rolf Mitzner[1], Karsten Holldack[1], Hartmut Zabel[4], Alexander Föhlisch[1,2], and Christian Schüßler-Langeheine[1] — [1]Helmholtz-Zentrum Berlin für Materialien und Energie GmbH, Germany — [2]Institut für Physik und Astronomie, Universität Potsdam, Germany — [3]II. Physikalisches Institut, Universität zu Köln, Germany — [4]Institut für Physik, Johannes Gutenberg-Universität Mainz, Germany

The wealth of studies in the field of ultrafast magnetic dynamics brought the understanding that the speed limit for spin manipulation comes from the achievable angular momentum transfer rate. In ferromagnets with net magnetization, any change of magnetic order requires transfer of angular momentum out of the spin system. Magnetic materials with non-parallel spins like antiferromagnets, offer the possibility to manipulate magnetic order by redistributing angular momentum within the spin system itself. We compare ferro (FM) - and antiferromagnetic (AFM) dynamics in one and the same material - metallic Dy - and find indeed clear differences. AFM spin order is faster manipulated by optical excitation than its FM counterpart. We assign the fast process in the AFM phase to an interatomic transfer of angular momentum within the spin system. Our findings point out a possible route towards ultrafast spin manipulation for magnetic devices.

MA 36.6 Wed 16:15 H34

Ultrafast magnetization dynamics FeRh — •Robert Carley[1], Manuel Izquierdo[1], Sebastian Carron[6], Tyler Chase[4], Bruce Clemens[4], Georgi Dakovski[6], Eric Fullerton[5], Patrick Granitzka[4], Alexander Gray[3], Stefan Günther[2], Daniel Higley[4], Emmanuelle Jal[3], Loïc Le Guyader[7], Joel Li[4], Serguei Molodtsov[1], Mike Minitti[6], Ankush Mitra[6], Alexander Reid[3], William Schlotter[6], Vojtech Uhlir[5], Joachim Stöhr[3], Hermann Dürr[3], Christian Back[2], Andreas Scherz[1], Alexander Yaroslavtsev[1], and Ruslan Kurta[1] — [1]European XFEL, Germany — [2]Universität Regensburg, Germany — [3]Stanford Institute for Materials and Energy Science, USA — [4]Stanford University, USA — [5]University of California San Diego, USA — [6]Linac Coherent Light Source, Stanford, USA — [7]Helmholtz Zentrum Berlin für Materialien und Energie, Germany

We report on an experimental study of the laser-driven antiferromagnetic (AFM) to ferromagnetic (FM) phase transition in FeRh using the time-, element-, and spatially resolving technique of resonant x-ray diffraction at the Fe L3 edge. We observe sub-ps magnetic transients followed by FM nucleation on the 10 ps timescale, and finally slower domain dynamics. This contribution will focus on the sub-ps dynamics, which provide a detailed insight into the microscopic mechanisms underlying the AFM-FM transition.

15 min. break

MA 36.7 Wed 16:45 H34

Temperature dependent laser induced magnetization switching in $Tb_{22}Fe_{69}Co_9$ ferrimagnetic thin film by photoelectron emission microscopy — •Ashima Arora, Lukas Gierster, Ahmet Ünal, and Florian Kronast — Helmholtz-Zentrum Berlin, Albert-Einstein Str. 15, 12489 Berlin, Germany

All optical helicity dependent switching has drawn a significant attention for data storage applications in the view of controlling the magnetic state of material without applying high magnetic fields. It has been shown in the previous studies that the magnetization of ferrimagnets like $Tb_{22}Fe_{69}Co_9$ can be altered by circularly polarized femtosecond laser pulses[1-2]. This magnetization reversal process involves a competition between different effects arising from laser heating, helicity dependent momentum transfer and dipolar fields. Using X-Ray photoelectron emission microscopy (PEEM), we distinguished the influence of the three effects using a μm sized laser spot [3]. To investigate the magnetic switching in greater detail, measurements were performed at different temperatures which show that the effect of helicity dependent switching is stronger at lower temperatures. We observe that the total area switched by a single circularly polarized femtosecond laser pulse and the average domain size, both increase with the sample temperature. These observations might be attributed to temperature dependent threshold in laser switching process.

1. S.Mangin et al., Nat. Mater. 13, 286-292 (2014)
2. C-H. Lambert et al., Science 345, 6202(2015)
3. L. Gierster et al., Ultramicroscopy (2015) doi:10.1016/j.ultramic.2015.05.016

MA 36.8 Wed 17:00 H34

Brillouin Light Scattering study of magnon-photon strong coupling in a split-ring resonator / YIG film system — •Stefan Klingler[1,2], Hannes Maier-Flaig[1,2], Rudolf Gross[1,2,3], Can-Ming Hu[4], Hans Hübl[1,2,3], Sebastian T. B. Goennenwein[1,2,3], and Mathias Weiler[1,2] — [1]Walther-Meißner-Institut, Bayerische Akademie der Wissenschaften, Garching, Germany — [2]Physik-Department, Technische Universität München, Garching, Germany — [3]Nanosystems Initiative Munich, Munich, Germany — [4]Department of Physics and Astronomy, University of Manitoba, Winnipeg, Canada

In coupled microwave resonator/magnetic hybrid systems an anticrossing of photonic and magnonic dispersions can occur.

Here, we use microfocused Brillouin Light Scattering (BLS) to study this magnon-photon coupling phenomenon. The BLS detection affords us with frequency-resolved detection of magnonic excitations. We employ a lithographically defined split-ring resonator (SRR) loaded with a 3 μm-thick Yttrium Iron Garnet (YIG) film grown by liquid phase epitaxy. We simultaneously record BLS spectra and the microwave transmission (MT) of the hybrid system as a function of external magnetic field magnitude and microwave excitation frequency. From this data, we find strong coupling of the magnonic and photonic modes with a coupling strength of ≈60 MHz at an excitation frequency of ≈5 GHz. Light-polarization dependent measurements confirm that BLS and MT spectroscopy are sensitive to the magnonic and photonic parts of the coupled magnon-photon mode, respectively.

MA 36.9 Wed 17:15 H34

Anomalously low magnetic damping of a metallic ferromagnet $\mathbf{Fe_{1-x}Co_x}$ — Martin Schoen[1,2], •Danny Thonig[3], Michael Schneider[1], Thomas Silva[1], Hans Nembach[1], Olle Eriksson[3], Olof Karis[3], and Justin Shaw[1] — [1]Quantum Electromagnetics Division, National Institute of Standards and Technology, USA — [2]Institute of Experimental and Applied Physics, University of Regensburg, Germany — [3]Department of Physics and Astronomy, University Uppsala, Sweden

Scaling of magnetic memory devices will require extremely low Gilbert damping. Ultra low damping (< 0.001), has only been found in nonmetallic materials such as YIG or Heusler alloys. Recent theoretical work by Mankovsky et al. [1], however, predict damping of about 0.0007 in metallic CoFe alloys at 10% Co concentration. Such low values of the damping are highly uncommon in conducting ferromagnetic systems.

To confirm the predictions, we preformed a systematic FMR studies of the damping in Co_xFe_{1-x} systems spanning the full alloy composition range. Our measurements are corroborated by first principle DFT calculations of the electron structure.

We found a minimum of the damping in FeCo at 25% Co concentration, consistent with density of states calculations at 25% Co. The minimum of the damping in $Co_{0.25}Fe_{0.75}$ exhibits a — for conducting ferromagnets unprecedented — low value of $\alpha = 0.0005$, showing the practicality of metal alloys for spintronics.

[1] Mankovsky et al., Phys. Rev. B 87, 014430 (2013)

MA 36.10 Wed 17:30 H34

Nonlinear spin-wave excitations at low magnetic bias fields — Hans G. Bauer[1], Peter Majchrak[1], Torsten Kachel[3], Christian H. Back[1], and •Georg Woltersdorf[1,2] — [1]Department of Physics, University of Regensburg, Universitätsstrasse 31, 93040 Regensburg, Germany — [2]Institute of Physics, Martin Luther University Halle-Wittenberg, Von-Danckelmann-Platz 3, 06120 Halle, Germany — [3]Institut for Methods and Instrumentation in Synchrotron Radiation Research, Helmholtz-Center Berlin for Materials und Energy, Albert-Einstein-Str. 15, 12489 Berlin, Germany

We investigate experimentally and theoretically the nonlinear magnetization dynamics in magnetic films at low magnetic bias fields. In the experiments we use X-ray magnetic circular dichroism to determine the number density of excited magnons in magnetically soft NiFe thin films. Our data show that the common Suhl instability model of nonlinear ferromagnetic resonance is not adequate for the description of the nonlinear behavior in the low magnetic field limit. Here we derive a model of parametric spin-wave excitation, which correctly predicts nonlinear threshold amplitudes and decay rates at high and at low magnetic bias fields. In fact, a series of critical spin-wave modes with fast oscillations of the amplitude and phase is found, generalizing the theory of parametric spin-wave excitation to large modulation amplitudes. Our results also show that it is not required to invoke a wave vector-dependent damping parameter in the interpretation of nonlinear magnetic resonance experiments performed at low bias fields.

MA 36.11 Wed 17:45 H34

Rayleigh-Jeans condensation of pumped magnons in thin film ferromagnets — •Andreas Rückriegel and Peter Kopietz — Institut für Theoretische Physik, Universität Frankfurt

We show that the formation of a magnon condensate in thin ferromagnetic films can be explained within the framework of a classical stochastic non-Markovian Landau-Lifshitz-Gilbert equation where the properties of the random magnetic field and the dissipation are determined by the underlying phonon dynamics. We have numerically solved this equation for a tangentially magnetized yttrium-iron garnet film in the presence of a parallel parametric pumping field. We obtain a complete description of all stages of the nonequilibrium time evolution of the magnon gas which is in excellent agreement with experiments. Our calculation proves that the experimentally observed condensation of magnons in yttrium-iron garnet at room temperature is a purely classical phenomenon which should be called Rayleigh-Jeans rather than Bose-Einstein condensation.

MA 36.12 Wed 18:00 H34

Relativistic theory of spin relaxation mechanisms in the Landau-Lifshitz equations of spin dynamics — •Ritwik Mondal, Marco Berritta, Pablo Maldonado, Alexandros Aperis, and Peter M. Oppeneer — Uppsala University, Uppsala, Sweden

Magnetization dynamics has been successfully applied to spin systems with phenomenological Landau-Lifshitz equations of motion [1]. Here, starting from the Dirac-Kohn-Sham equation we derive the relativistic equation of motion of angular momentum in a magnetic solid taking into account the spin-orbit coupling. This equation of motion can be rewritten in the form of the well-known Landau-Lifshitz equation plus additional relativistic terms which describe the various electronic spin relaxation mechanisms. Thus we derive a damping parameter of Gilbert type [2] (see also [3]). Further, we discuss the dynamics of the total angular momentum within the relativistic Dirac framework including exchange interactions of Heisenberg type.

[1]L.D. Landau and E.M. Lifshitz, Phys. Z. Sowjetunion **8**, 101 (1935). [2]T.L. Gilbert, IEEE Trans. Magn. **40**, 3443 (2004). [3]M.C. Hickey and J.S. Moodera, Phys. Rev. Lett. **102**, 137601 (2009).