MA 5: Magnetization/Demagnetization Dynamics

Time: Monday 9:30–12:15 Location: HSZ 401

MA 5.1 Mon 9:30 HSZ 401

Principle spin-lattice dynamics studies mediated by RKKY and dipole-dipole interaction — •Danny Thonig[1], Jacob Persson[1], Johan Hellsvik[2], Lars Bergqvist[2], Anna Delin[2], Olle Eriksson[1], and Jonas Fransson[1] — [1]Department of Material Theory, Uppsala University, Sweden — [2]Department of Materials and Nano Physics, KTH, 16440 Kista, Sweden

The understanding how magnons couple with phonons is of fundamental importance. It is dominantly caused by distance dependent exchange between the magnetic moment [1], such as RKKY-like Heisenberg or dipole-dipole interaction. Both exhibits changes in the magnetic order, say from ferro to antiferromagnetic states, related to the crystal structure, which is affected by displacements and call for deeper studies.

We report on an investigation of atomistic coupled spin-lattice dynamics by means of the Landau-Lifshitz-Gilbert and Newton equation. The exchange and force constant parameters of the Hamiltonian are approached by RKKY and dipole-dipole as well as Born-Landé exchange, respectively.

For low dimensional systems, we focus on the evolution from disordered to ordered states in dependence on temperature, island size, and external magnetic field. It turns out that spin and displacements have a crucial influence on each other, especially near magnetic order changes.

[1] Y. Tokura, S. Seki, and N.Nagaosa, Rep. Prog. Phys. 77, 076501 (2014)

MA 5.2 Mon 9:45 HSZ 401

Modeling of ultrafast magnetization dynamics in synthetic ferrimagnets — •Stefan Gerlach[1], Laszlo Oroszlany[2], Denise Hinzke[1], Steffen Sievering[1], Sönke Wienholdt[1], Laszlo Szunyogh[2], and Ulrich Nowak[1] — [1]Fachbereich Physik, Universität Konstanz, D-78457 Konstanz, Germany — [2]Department of Theoretical Physics, Budapest University of Technology and Economics, Budafoki ut 8., HU-1111 Budapest, Hungary

Based on numerical simulations, we demonstrate thermally induced magnetic switching in synthetic ferrimagnets composed of multilayers of rare earths and transition metals. Our findings show that deterministic magnetization reversal occurs above a certain threshold temperature if the ratio of transition metal atoms to rare earth atoms is sufficiently large. Surprisingly, the total thickness of the multilayer system has little effect on switching. We further provide a simple argument to explain the temperature dependence of the reversal process.

MA 5.3 Mon 10:00 HSZ 401

The role of magnetic anisotropy on spin pumping revealed in epitaxial Fe/NM (Pt, Pd, Au) systems — •Sascha Keller, Laura Mihalceanu, Andres Conca, Matthias R. Schweizer, Jochen Greser, Burkard Hillebrands, and Evangelos Th. Papaioannou — Fachbereich Physik, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663 Kaiserslautern, Germany

In spintronics, which extends the classical electronics with the spin of electrons as additional degree of freedom, the spin current-to-charge current conversion is an important task for possible interfaces to microelectronic technologies. The spin pumping (SP) and inverse spin Hall effect (ISHE) in bilayers consisting of a ferromagnetic (FM) layer and an attached non-magnetic metal (NM) layer therefore allow for such a conversion. However the role of intrinsic crystalline magnetic anisotropy has not been discussed in the topic of spin pumping, yet. We address this question through bilayers consisting of metallic FM and NM capping layers of high epitaxial quality grown by molecular beam epitaxy (MBE). Due to the use of metallic ferromagnets employing an angular resolved spin pumping measurement setup is crucial to separate spin rectification effects from ISHE. There the external magnetic field is rotated in-plane and the effects can be differentiated due to the different angular dependences of those effects. The epitaxially grown FM/NM interfaces are strongly affecting the spin pumping and rectification effects due to the structural quality of the interface and the intrinsic magnetic anisotropy of the FM. The Carl Zeiss Stiftung is gratefully acknowledged for financial support.

MA 5.4 Mon 10:15 HSZ 401

Dynamics of coupled topological Solitons — •Fabian Kloodt[1], Robert Frömter[1,2], Philipp Staeck[1], Susanne Kuhrau[1], and Hans Peter Oepen[1,2] — [1]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Jungiusstraße 11, 20355 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, 22761 Hamburg, Germany

In the framework of the Thiele-equation magnetic vortices and antivortices can be treated as quasi-particles, i.e. solitons. Confining a single (anti-)vortex in a magnetic microstructure causes linear restoring forces, which results in an oscillator equation describing the field-driven motion of individual solitons. Using TR-SEMPA [1] we investigate coupling effects in vortex-antivortex chains in patterned FeCoSiB-structures. While the vortices exhibit a clear oscillation the antivortices show no apparent motion. Both types of magnetic solitons are mutually coupled via the domain energy (part of the stray-field energy), resulting in a coupled oscillation mode under HF-field excitation. TR-SEMPA results and micromagnetic simulations stand in excellent agreement indicating that coupling dominates the motion of the individual solitons.

[1] R. Frömter, Appl. Phys. Lett. 108, 142401 (2016).

MA 5.5 Mon 10:30 HSZ 401

Electron dynamics driving ultrafast magnetization dynamics in itinerant ferromagnets and alloys — •Sebastian Weber and Baerbel Rethfeld — Department of Physics and Research Center Optimas, University of Kaiserslautern, Erwin-Schroedinger-Strasse 46, 67663 Kaiserslautern, Germany

Irradiating ferromagnetic films with an ultrashort laser pulse leads to a quenching of the magnetization on a subpicosecond timescale [1]. With help of a spin-resolved Boltzmann description, which allows to describe microscopic collision processes including spin-flips, we have identified the equilibration of chemical potentials of majority and minority electrons as a driving force for ultrafast magnetization dynamics [2].
Recent experiments have revealed element-specific dynamics in exchange coupled ferromagnetic alloys [3]. We set up a microscopic model to trace the electron dynamics with pin-resolution and in dependence on the material in the alloy. We show first results of the interplay between relaxation processes.

[1] E. Beaurepaire et al., PRL 76, 4250 (1996)
[2] B. Y. Mueller et al., PRL 111, 167204 (2013)
[3] S. Mathias et al., PNAS 109, 4792 (2012)

15 min. break.

MA 5.6 Mon 11:00 HSZ 401

Measuring the magnetization dynamic of Fe(110) using a novel high harmonic source. — •Rafael Gort — ETH Zürich, Laboratorium für Festkörperphysik, 8093 Zürich

As ultrafast demagnetization is partially a spin transport effect, the continuously growing field of spintronics is related to femtosecond magnetization dynamics.

Energy resolved photoemission experiments in principle provide the possibility for direct observation of the electrons that contribute to the macroscopic magnetization. However, for a long time the spin detectors have not been efficient enough for spin and time resolved electron spectroscopy of the entire valence band. The development of imaging spin detectors increase the detection efficiency by several orders of magnitude compared to the well-known Mott spin detector.

A spin detector has been developed, where spin selectivity is achieved by low energetic electron scattering at a Iridium crystal. In addition, a very compact and stable high harmonic source has been designed, with the goal of delivering short VUV pulses for just one single center wavelength.

We present first measurements of spin and time resolved photoemission spectra of ultrafast demagnetization in iron. We intend to compare the spin dynamics of electrons at the Fermi energy to the laser-induced change of the exchange splitting. This will lead to deeper insights into transport phenomena within the valence band.

MA 5.7 Mon 11:15 HSZ 401

Ultrafast Lorentz microscopy of nanoscale magnetization dy-

namics — •Nara Rubiano da Silva[1], Marcel Möller[1], Tim Eggebrecht[2], Jan Gregor Gatzmann[1], Armin Feist[1], Ulrike Martens[3], Henning Ulrichs[2], Markus Münzenberg[3], Claus Ropers[1], and Sascha Schäfer[1] — [1]4th Physical Institute, University of Göttingen, Germany — [2]1st Physical Institute, University of Göttingen, Germany — [3]Interface and Surface Physics, University of Greifswald, Germany

Lorentz microscopy is an established technique for the nanoscale mapping of magnetic structures, exceeding the diffraction-limited resolution of magneto-optical microscopy [1]. However, time-resolved implementations of this method have remained elusive, due to the lack of pulsed electron sources of sufficient brightness and coherence.

Here, we present the implementation of Lorentz microscopy within the ultrafast transmission electron microscope (UTEM) recently developed in Göttingen [2]. We employ highly coherent, sub-ps electron pulses to study laser-induced demagnetization dynamics in permalloy nanostructures. Our approach offers fascinating prospects for elucidating ultrafast spin dynamics and light-induced magnetic textures [3] on the nanoscale.

[1] N. O. Urs *et al.*, AIP Advances **6** (2016).
[2] A. Feist *et al.*, under revision, arXiv:1611.05022 (2016).
[3] T. Eggebrecht *et al.*, under revision, arxiV:1609.04000 (2016).

MA 5.8 Mon 11:30 HSZ 401

Pump-Probe Holographic Imaging of Nanoscale Magnetic Domains — S. Schleitzer[1], L. Müller[1], •M. Riepp[1], A. Philippi-Kobs[1], W. Roseker[1], C. Gutt[1], M. H. Berntsen[1], B. Pfau[2], D. Weder[2], J. Geilhufe[2], C. von Korff Schmising[2], B. Vodungbo[3], J. Gautier[3], K. Li[3], G. Malinowski[3], B. Tudu[3], F. Capotondi[4], E. Pedersoli[4], M. Kiskinova[4], J. Lüning[3], S. Eisebitt[2], and G. Grübel[1] — [1]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [2]Technische Universität Berlin, Berlin, Germany — [3]Université Pierre et Marie Curie, Paris, France — [4]Elettra-Sincrotrone Trieste, Basovizza, Italy

While ultrafast magnetization dynamics of homogeneously magnetized samples has been studied by optical pump-probe techniques since decades, it is still an open question how nanoscale magnetic domain patterns react to an ultrashort optical stimulus. Here, we report on an optical pump–free electron laser (FEL)-probe imaging experiment on a $(Co_{0.4nm}/Pd_{0.2nm})_{30}$ multilayer deposited on a Si_3N_4 membrane. The multilayer exhibits a perpendicular magnetic anisotropy and a disordered maze-domain pattern (domain size of 80 nm). The experiment was conducted at DiProI beamline at FERMI@Elettra using FEL radiation tuned resonantly to the M_3 absorption edge of cobalt. By using Fourier transform holography, the real-space domain configuration could be directly retrieved unambiguously from the scattering data. We fixed the pump-probe delay time to 1 ps and followed the evolution of the domain pattern at different pump fluences revealing ultrafast demagnetization in real space on the nanoscale.

MA 5.9 Mon 11:45 HSZ 401

Quenching of the Resonant Magnetic Scattering Cross Section by Ultra-Short Free-Electron Laser Light Pulses — •L. Müller[1], M.H. Berntsen[2], W. Roseker[1], A. Philippi-Kobs[1], K. Bagschik[3], J. Wagner[3], R. Frömter[3], F. Capotondi[4], E. Pedersoli[4], M.B. Danailov[4], M. Kiskinova[4], H.P. Oepen[3], and G. Grübel[1] — [1]Deutsches Elektronen-Synchrotron DESY, FS-CXS, Hamburg, Germany — [2]KTH Royal Institute of Technology, Stockholm, Sweden — [3]Institut für Nanostruktur- und Festkörperphysik, Universität Hamburg, Hamburg, Germany — [4]Elettra Sincrotrone Trieste, Basovizza, Italy

The new free-electron laser (FEL) sources provide radiation with unprecedented parameters in terms of ultrashort pulse length, high photon flux, and coherence. These properties make FELs ideal tools for studying ultrafast dynamics in matter on a previously inaccessible level. Yet, FELs do not only probe matter, but can also drive it into highly excited states which are otherwise inaccessible. For example, a state can be reached in which resonant magnetic scattering is highly suppressed [1].

Here, we report on a resonant magnetic scattering experiment, where the focussed FEL light pulses probe the magnetic domain system of a Co/Pt multilayer thin film with perpendicular magnetic anisotropy. Both, single and double FEL pulses at different fluences are used to follow the quenching of the resonant scattering efficiency.

[1] L. Müller et al., Phys. Rev. Lett. **110**, 234801 (2013).

MA 5.10 Mon 12:00 HSZ 401

Imaging of the dynamic magnetoelastic effect in ferromagnetic layers induced by surface acoustic waves — Michael Foerster[1], Ferran Macià[2,3], Nahuel Statuto[3], Simone Finizio[4,5], •Alberto Hernández-Mínguez[6], Sergi Lendínez[3], Paulo Santos[6], Josep Fontcuberta[2], Joan Manel Hernàndez[3], Mathias Kläui[4], and Lucia Aballe[1] — [1]ALBA Synchrotron Light Source, Spain — [2]Institut de Ciència de Materials de Barcelona, Spain — [3]University of Barcelona, Spain — [4]Johannes Gutenberg Universität Mainz, Germany — [5]Paul Scherrer Institut, Switzerland — [6]Paul-Drude-Institut für Festkörperelektronik, Germany

The exploitation of magnetoelasticity is a promising alternative to the use of magnetic fields for the dynamic control of magnetization states of nanoelements. In this contribution, we study the effect of surface acoustic waves (SAWs) on the magnetization dynamics of 20 nm thick nickel nanostructures deposited on a piezoelectric substrate. By combining X-ray magnetic circular dichroism with photoemission electron microscopy, and synchronizing the SAW frequency with the X-rays repetition rate, we obtain simultaneous stroboscopic images of the magnetization domains and the SAW propagating along the nanostructures with temporal resolution down to the picosecond scale. Our results demonstrate a time delay between the magnetization dynamics and the SAW-induced strain field that depends on the orientation of the magnetic domains with respect to the SAW propagation direction. The versatility of our experimental technique provides a new pathway to the quantitative study of dynamic magnetoelastic effects at the nanoscale.