# MA 33 Spin-Dynamics, Magnetization Reversal III

Time: Thursday 15:15–18:30 Room: HSZ 403

MA 33.1 Thu 15:15 HSZ 403

**Current-induced microwave excitations of nanomagnets made of single-crystalline iron** — •Ronald Lehndorff, Henning Dassow, Reinert Schreiber, Daniel E. Bürgler, and Claus M. Schneider — Institut für Festkörperforschung, Foschungszentrum Jülich GmbH, D-52425 Jülich, Germany

The magnetization dynamics of nanomagnets under the influence of a spin-polarized current is of great interest since Slonczewski and Berger predicted the possibilities of magnetization switching and steady precessions in 1996 [1, 2].

We study the magnetization dynamics of nanomagnets made of epitaxial Fe with diameters of 100 nm to 200 nm and thicknesses of 2 nm relative to an extended Fe layer of 10 nm thickness that is magnetically hardened by interlayer exchange coupling over Cr to a 14 nm Fe layer.

We measure magnetoresistance and resistance versus current to characterize our samples. The switching behavior shows clear four-fold in-plane crystalline anisotropy of the Fe layers. Varying the field direction relative to the crystalline axes can assist the current-induced switching process.

We detect microwave signals due to steady large angle precessions of the magnetization and study the dependence on current, magnetic field and field angle relative to the crystalline axes.

[1] J.C. Slonczewski, J. Magn. Magn. Mater. **159**, L1 (1996)
[2] L. Berger, Phys. Rev. B **54**, 9353 (1996)

MA 33.2 Thu 15:30 HSZ 403

**Magnetization switching by spin transfer torque in magnetic nanostructures** — •Nicolas Müsgens[1], Georg Richter[1], Barbaros Özyilmaz[1,2], Michael Fraune[1], Matthias Hawraneck[1], Bernd Beschoten[1], Matthias Bückins[3], Joachim Mayer[3], and Gernot Güntherodt[1] — [1]II. Phyikalisches Institut , RWTH Aachen, and Virtual Institut of Spin Electronics (ViSel), Templergraben 55, 52056 Aachen, Germany — [2]Department of Physiks, Columbia University, New York, NY 10027, USA — [3]Gemeinschaftslabor für Elektronenmikroskopie, RWTH Aachen, 52056 Aachen, Germany

The transfer of a torque of spin-polarized currents onto macroscopic magnetizations has been investigated in confined magnetic nanostructures. Nanostencil masks are used to define the device dimensions (sub 100 nm2) prior to the deposition of the thin Co/Cu/Co stack with perpendicular current. The masks consist of a focused-ion-beam (FIB) milled nano-aperture in a top metal layer on top of an insulator and an underlying pre-patterned bottom electrode. The insulator causes an undercut by its selective wet etching. The approach is demonstrated by spin transfer torque-induced magnetization dynamics, giving rise to a giant magneto-resistance effect of 0.3 % at room temperature.

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MA 33.3 Thu 15:45 HSZ 403

**Probing the Electron and Spin Dynamics of 3d-transition Elements in Real-Time** — •Bernd Heitkamp, L. Heyne, H. A. Dürr, and W. Eberhardt — BESSY, Berlin, Germany

We report on pump-probe experiments investigating the physical properties of 3d transition elements. An intensive fs laser pump pulse is used to heat the electron system, which triggers a fast quenching of the magnetic moments. Observing the energy distribution of the hot electron and spin subsystem on a fs time scale after excitation gives a deep insight into the interplay of electron relaxation, spin-orbit coupling and spin-lattice relaxation. Time-resolution of the experiment is given by a fs-laser system. The photoelectron emission microscope (PEEM) allows to investigate structures with a spatial resolution well below one micrometer. Measuring the time-of-flight of the emitted photoelectrons by means of a delayline detector determines the energy resolution. In addition sensitivity to the photoelectron spin is given by SPLEED-detector. Experiments on Nickel and Cobalt show a demagnetization below one picosend while the electron subsystem is still not thermalized. Both the demagnetization and the relaxation are strongly affected by the dielectric response of the nanoscale structures.

MA 33.4 Thu 16:00 HSZ 403

**Decrease of entropy in magnetic particles** — •H.J. Elmers[1], A. Krasyuk[1], F. Wegelin[1], S.A. Nepijko[1], A. Conca[1], G. Schönhense[1], M. Bolte[2], and C.M. Schneider[3] — [1]Johannes Gutenberg-Universität Mainz, Institut für Physik, Staudingerweg 7, D-55099 Mainz — [2]Universität Hamburg, Institut für Angewandte Physik, Jungiusstrasse 11, D-20355 Mainz — [3]Forschungszentrum Jülich GmbH, Institut für Festkörperforschung IFF-6, D-52425 Jülich

In a closed system entropy maximization tends to decrease order. An open system with a constant throughput of energy, however, allows for an increase of local order. Exciting micron-sized permalloy particles with an oscillating external field we found an example for this phenomenon. The external oscillating field is the energy source while the internal damping plays the role of the sink. In a rectangular platelet (16 $\mu$m×32 $\mu$m×10 nm) the equilibrium magnetization state is formed by a symmetric flux-closure domain pattern comprising two equally-sized domains separated by a 180 degree domain wall. The external oscillating field is applied off-resonance along the short side of the platelet, thus exciting a precessional motion of the magnetization. The system reacts by increasing one magnetic domain at the expense of the others. The final state has uniform magnetization and is thus completely ordered. The basic mechanism, revealed by both stroboscopic imaging with time-resolved photoelectron emission microscopy and computer simulation, is the decrease of the resonance frequency in the larger domain. This leads to larger energy dissipation in the system, allowing increasing order with increasing entropy.

MA 33.5 Thu 16:15 HSZ 403

**Nanosecond magnetization dynamics with pulsed high fields in microcoils** — •Martin Weisheit[1,2], Marlio Bonfim[1], Vitoria Barthem[1], Sebastian Fähler[2], and Dominique Givord[1] — [1]Laboratoire Louis Neél, CNRS Grenoble, 25 av. des Martyrs, F-38042 Grenoble Cedex 9, France — [2]Institute for Metallic Materials, IFW Dresden, Helmholtzstr. 20, D-01069 Dresden, Germany

In order to study the switching of highly anisotropic magnetic materials, which can have coercivities of a few T, pulsed magnetic fields may be employed. Very high fields of up to 50 T can be generated by short current pulses in microcoils [1]. Coils with inner diameters of 50 $\mu$m are used, for which pulse energies below 1 J are sufficient, allowing for very compact and fast designs. Since field rise times are of the order of 1 T/ns, the dynamics of magnetization behavior become apparent. This is demonstrated by polar Kerr effect measurements on FePt thin films, where the observed coercivity is drastically increased compared to $H_{\mathrm{c,static}} = 5.6$ T as measured by VSM [2]. Simulations of the magnetization response to the external field pulse, using a no-precession approximation of the Landau-Lifshitz-Gilbert equation, compare well with the pulsed field measurements.

[1] M. Bonfim, K. Mackay, S. Pizzini, M.-L. Arnou, A. Fontaine, G. Ghiringhelli, S. Pascarelli, and T. Neisius, J. Appl. Phys. **87** (2000) 5974
[2] M. Weisheit, L. Schultz, and S. Fähler, J. Appl. Phys. **95** (2004) 7489

MA 33.6 Thu 16:30 HSZ 403

**Bloch line generation in cross-tie walls by fast magnetic field pulses** — •Andreas Neudert, Jeffrey McCord, Rudolf Schäfer, and Ludwig Schultz — IFW Dresden, Postfach 270116, 01171 Dresden

In ferromagnetic films with an intermediate thickness of 30 to 90 nm cross-tie walls are observed. They consist of a sequence of circular and cross Bloch lines (also called vortex and antivortex) that are connected by 90° Neel walls. Additional 90° Neel walls emerge from the cross Bloch lines and form the "legs"of the cross-tie wall. We investigated the influence of a pulsed magnetic field (amplitude 400 A/m, width 1.2 ns) applied perpendicular to the wall plane onto a constrained cross-tie wall in a 80 $\mu$m x 160 $\mu$m permalloy rectangle of 50 nm thickness. The equilibrium cross-tie spacing of about 15 $\mu$m is reached after demagnetizing the sample with a magnetic ac-field. By applying the pulsed magnetic field with a repetition rate of 23 MHz additional Bloch lines are created and the cross-tie spacing decreases to about 5 $\mu$m. This Bloch line generation is not triggered by the repetition rate of the pulsed magnetic field as shown by using a low repetition rate pulse train of 0.2 Hz but by the fast rise time of the field pulses. A comparison with micromagnetic calculations will be given.

MA 33.7 Thu 16:45 HSZ 403

**Ultrafast Demagnetization of Ferromagnetic Films Probed by XMCD** — •Christian Stamm, Cosmin Lupulescu, Hermann Dürr, and Wolfgang Eberhardt — BESSY, Albert-Einstein-Str. 15, 12489 Berlin, Germany

We investigate the dynamic response of magnetic thin films subjected to high-intensity fs laser pulses. Using the X-ray magnetic circular dichroism (XMCD) we observe the evolution of the magnetization as a function of time delay between laser pump and X-ray probe pulse. This technique complementary to the magneto-optic Kerr effect, allows us to separately determine spin and orbital moments by a sum rule calculation. Our goal is to get new insight into the process of fs demagnetization, especially concerning the conservation of the total angular momentum.

The experiments were performed at the BESSY Synchrotron source using gated detection of single X-ray bunches following a pump pulse from a synchronized fs laser. During normal operation, the X-ray pulse length is ˜50 ps. To further improve the time resolution we also used the ”low-alpha” mode of the Synchrotron reducing the pulse length down to 5 ps.

We find that a Ni thin film with in-plane magnetization and a CoPd multilayer with perpendicular anisotropy both can be demagnetized in less than 10 ps. Additionally, X-ray dichroism spectra are recorded at different time delays, allowing the determination of spin and orbital moments of the excited film. The use of fs X-ray pulses from the slicing source currently under commissioning at BESSY will further increase the time resolution of our experiments to the fs regime.

MA 33.8 Thu 17:00 HSZ 403

**Magnetization dynamics triggered by photo-conductive switches** — •Matthäus Pietz[1], A. Parge[1], M. Djordjevic[1], A. Förster[2], and M. Münzenberg[1] — [1]IV. Phys. Inst. Universität Göttingen — [2]Inst. für Schichten und Grenzflächen (ISG1) Forschungszentrum Jülich

Ultrafast photoconductive switches, based on metal-semiconductor-metal contact pads using low temperature grown GaAs as a semiconductor, deliver the fastest current pulses on a chip so far. Using fs pulses from a Ti:Sapphire laser for the excitation of the carriers, current pulses of a few picoseconds in length are generated. The pulses are characterised with autocorrelation technique. We demonstrate that using amplified laser pulses of 1 $\mu$J energy we are able to create current pulses with an amplitude of 1 Ampere and 3 ps length. The field pulse can be used to trigger the magnetization dynamics in a magnetic nanostructure. Therefore, magnetic structures on a strip line with the help of e-beam lithography are prepared, with the aim to explore magnetic Eigen mode oscillations and extrinsic as well as intrinsic damping parameters in a pump-probe experiment with ps time resolution.

MA 33.9 Thu 17:15 HSZ 403

**Intrinsic and non-local Gilbert Damping parameter in all optical pump-probe experiments** — •Marija Djordjevic[1], J. Walowski[1], G. Eilers[1], M. Münzenberg[1], and J.S. Moodera[2] — [1]IV. Physikalisches Institut, Universität Göttingen — [2]Francis Bitter Magnet Laboratory, MIT, Cambridge, USA

With the time resolution inherent using femtosecond laser pulses in all optical pump-probe experiments, the basic time constants of magnetic precessional modes, as well as the energy dissipation processes determining the Gilbert damping, can be studied. Our focus is to explore the underlying damping mechanisms and how they can be controlled. The non-local Gilbert damping due to evanescent spin currents can be studied at double layers (FM/NM), in which the thickness of the FM layer is varied. The precession moment emits a dynamic spin current that is subsequently damped in a material with a strong spin-orbit coupling. An enhancement in the Gilbert damping parameter for Ni/Pd and Ni/Cr double layers which is inversely proportional to the thickness of the Ni layer is observed. The frequency dependence of damping parameter for Ni/Cr films monitors presence of two-magnon scattering processes. The non-local damping for different Ni/NM double layers is found not to simply scale with the spin-orbit coupling constant. Increased roughness as well as the (non)compatibility of the DOS at $E_F$ of Ni and NM, have to be included to model the damping. It will be of special interest to connect the elementary relaxation mechanisms to the origin of non-local Gilbert damping, as it is seen on the LLG timescale.

MA 33.10 Thu 17:30 HSZ 403

**Magnetization dynamics in all optical pump-probe experiments** — •Marija Djordjevic[1], J. Walowski[1], A. Parge[1], M. Münzenberg[1], and J.S. Moodera[2] — [1]IV. Physikalisches Institut, Universität Göttingen — [2]Francis Bitter Magnet Laboratory, MIT; Cambridge, USA

The study of magnetization dynamics on the femtosecond timescale is an important task for the implementation of future spintronics. In all optical pump-probe experiments the Ti:Sapphire laser pulses amplified with a regenerative amplifier (RegA 9000, 1 $\mu$J pulse energy) are used to demagnetize a 50 nm Ni film and to follow the magnetization relaxation with 80 fs time resolution. Magnetization precession is triggered with a laser induced change in the anisotropy field. The demagnetization rate is controlled with the pump laser fluence. Different precession modes are observed in the range from 1.5 GHz up to 13 GHz. In the time-resolved spectrum an incoherent magnon background, a coherent homogeneous precession mode and a standing spin wave mode are observed. All those contributions are strongly dependent on the amplitude and the orientation of the external field as well as on the pump laser fluence. The corresponding Gilbert damping parameter is found to be dependent on the precession mode, taking values from $\alpha = 0.05$ for very low up to $\alpha = 0.25$ for highly damped modes. The parameter changes with the variation of the field angle, the field strength and the height of the excitation amplitudes. This indicates mode dependent energy dissipation and mode conversion mechanisms.

MA 33.11 Thu 17:45 HSZ 403

**Femtosecond Spin-Dependent electron Dynamics in Co thin films** — •Mirko Cinchetti, Marina Sánchez Albaneda, Oleksiy Andreyev, Jan-Peter Wüstenberg, Michael Bauer, and Martin Aeschlimann — University of Kaiserslautern, Physics Department, Erwin Schroedinger-Str. 46, 67663 Kaiserslautern, Germany

Using the energy-, spin- and time-resolved two-photon photoemission technique, we have been able to follow the ultrafast spin-dependent electron dynamics in an epitaxially grown Co thin film. We observe that the time evolution of the spin polarization of unoccupied intermediate states (lying between the Fermi and the vacuum level) shows remarkable differences in dependence of the energy of the unoccupied state itself. In particular, for high intermediate states energies we find an increase of the polarization within the first 50 fs, which is due to the lifetime difference between spin-up and spin-down electrons. On the other hand, at low energies we find a modification of this behavior up to 700 fs. This is mainly due to secondary electrons which are scattered into the intermediate state, leading to refilling of the state itself. Within these 700 fs we can distinguish between a spin-selective region (with almost no spin-flips) and a spin-flip region, where a dramatic drop in the polarization is observed. The reasons for this behavior are discussed.

MA 33.12 Thu 18:00 HSZ 403

**Ultrafast demagnetization dynamics of ferromagnetic materials** — •Tobias Roth, Dorothea Hoffmann, and Martin Aeschlimann — Fachbereich Physik, TU Kaiserslautern, Erwin-Schrödinger Str.46, 67663 Kaiserslautern

The response of the magnetization to an ultrashort femtosecond laser pulse has been investigated by different techniques in the last decade but it still remains a highly controversial topic with respect to the involved microscopic processes. Up to now most of the investigations were based on ultrathin samples like Ni or CoPt3 with a low Curie temperature. The availability of very intense laser pulses delivered from a multipass amplifier system of 1 kHz repetition rate provides the experimental precondition to do time resolved measurements on Co, the material with the highest Curie point among the 3d transition metals. We apply the longitudinal MOKE in a bi-chromatic pump-probe technique to obtain a time resolved response of the magnetic system. By choosing a different wavelength for the pump and probe the well known ”bleaching”, an optical effect - caused by a change in the occupation number in a highly non equilibrium state - can be suppressed; therefore we have access to the pure magnetization. Our results exhibit a distinct demagnetization effect of around 50 % which is reached 750 fs after the pump pulse has impinged on the sample.

MA 33.13 Thu 18:15 HSZ 403

**Magnetization dynamics in rare-earth orthoferrites** — •Carmine Antonio Perroni, Ansgar Liebsch, Andreas Bringer, and Simon Woodford — Institute of Solid State Research (IFF), Research Center Juelich, Juelich 52428, Germany

Recently an ultrafast non-thermal control of magnetization has become feasible in canted antiferromagnets through instantaneous photomagnetic pulses [A.V. Kimel et al., Nature 435, 655 (2005)]. In this experiment circularly polarized femtosecond laser pulses set up a strong magnetic field through the inverse Faraday effect exciting non-thermally the spin dynamics of dysprosium orthoferrites. A theoretical study of magnetization dynamics is performed by using a model for orthoferrites based on a general form of free energy and by solving coupled sublattice Landau-Lifshitz-Gilbert equations. Due to the inverse Faraday effect and the non-thermal excitation, the effect of the laser is simulated analyzing the effect of magnetic field Gaussian pulses on time scales of the order of hundred femtoseconds. As a result, the magnetization oscillates around the initial equilibrium position with amplitudes in agreement with experiment. The simulations are pursued considering the effect of the temperature and of the field pulse along the x-axis in order to excite a different mode as obtained in the experiment. Finally the consequences of a double pump and of a large number of pulses on the magnetization dynamics are analyzed.