MA 38: Magnetization Dynamics IV

Time: Wednesday 14:45–17:15 Location: HSZ 403

MA 38.1 Wed 14:45 HSZ 403

Monitoring Vortex Dynamics and Vortex Core Polarization with Magnetic Tunnel Junctions — •Hermann Stoll[1], Matthias Noske[1], Karsten Rott[2], Markus Sproll[1], Matthias Kammerer[2], Michael Curcic[1], Bartel Van Waeyenberge[3], Günter Reiss[2], and Gisela Schütz[1] — [1]MPI für Metallforschung, Stuttgart — [2]Universität Bielefeld — [3]Ghent University, Belgium

Nakano et al. [1] have shown, that a magnetic tunnel junction (MTJ) placed on a micron-sized vortex element is capable of detecting gyrotropic motion and vortex core polarization when the vortex is excited by an ac current. However, problems occurred by crosstalk between the excitation current and the MTJ output. We have virtually eliminated this drawback by taking advantage of a sophisticated lock-in technique. In that way we would like to demonstrate a 1 bit vortex V(ortex)MRAM - with electric write and read-out - where data is stored in the out-of-plane magnetization of the vortex core, showing up or down - in a Permalloy vortex structure, 0.5 microns in diameter. In addition, our technique allows us to perform table-top experiments on vortex dynamics and vortex core reversal and can replace microscopic techniques (e.g., X-ray or MFM microscopy) in many cases. We will proof this in a second example where we have measured the frequency and amplitude dependence of the gyrotropic eigenmode of a vortex structure in an external static magnetic field. We will compare our findings with similar results [2] achieved by Magnetic Resonance Force Microscopy (MRFM). [1] K. Nakano et al., Applied Physics Express 3 (2010) 053001 [2] P. Pigeau et al., APL 96, 132506 (2010)

MA 38.2 Wed 15:00 HSZ 403

Controlled Vortex Core Reversal by Excitation of Spin Wave Modes — •Matthias Kammerer[1], Markus Weigand[1], Michael Curcic[1], Matthias Noske[1], Markus Sproll[1], Hermann Stoll[1], Bartel Van Waeyenberge[2], Georg Woltersdorf[3], Christian H. Back[1], and Gisela Schütz[3] — [1]MPI für Metallforschung, Stuttgart — [2]Ghen University, Belgium — [3]Universität Regensburg

It is well known, that magnetic vortex core reversal can be achieved by excitation of the (sub-GHz) vortex gyromode [1,2]. Surprisingly our experiments and micromagnetic simulations show an unidirectional vortex core switching by excitation of magneto static spin waves at frequencies more than an order of magnitude higher. These results were obtained with time-resolved magnetic imaging at the scanning X-ray microscope MAXYMUS at BESSY II, Berlin. Circular Permalloy platelets have been excited with in-plane rotating magnetic field bursts at GHz frequencies. Imaging could be performed with 30 ps time resolution. Vortex state structures possess spin wave eigenmodes arising from the magneto-static interaction. The interaction between these modes and the gyrotropic mode breaks the cylindrical symmetry of the micromagnetic objects, leading to a frequency splitting of the spin wave modes with opposite rotation senses. We could demonstrate [3] that the unidirectional vortex core reversal process is not limited to the gyrotropic mode but is a general mechanism when azimuthal modes (with m = +/- 1) are excited. [1] B. Van Waeyenberg et al., Nature 444, 461 (2006) [2] M. Curcic et al., PRL 101, 197204 (2008) [3] M. Kammerer et al., http://arxiv.org/abs/1008.4719

MA 38.3 Wed 15:15 HSZ 403

Fast and Selective Switching of the Vortex Core with Orthogonal Magnetic Pulses — •Matthias Noske[1], Markus Weigand[1], Bartel Van Waeyenberge[2], Hermann Stoll[1], Arne Vansteenkiste[2], Matthias Kammerer[1], Michael Curcic[1], Markus Sproll[1], Georg Woltersdorf[3], and Gisela Schütz[1] — [1]MPI for Metals Research, Stuttgart — [2]Department of Solid State Science, Ghent University, Belgium — [3]Department of Physics, Regensburg University

Reliable, low-power and selective switching of the magnetic vortex core using rotating magnetic fields has been demonstrated by [1] and has potential application in vortex random access memory as discussed in [2]. However, when rotating RF magnetic fields are applied, the vortex will gyrate a few times before the core polarity switches and a few times after until it reaches the equilibrium position again. In contrast, orthogonal pulses can cause switching after less than one gyration period. Our micromagnetic simulations and experiments prove that the vortex core in sub-micron sized permalloy structures can be unequivocally and unidirectionally reversed by two carefully designed orthogonal magnetic in-plane pulses. Additionally, by tuning the length of the second pulse, the vortex displacement after switching can be minimized, effectively quenching the residual vortex motion. The time-resolved experiments were conducted at the newly installed scanning X-ray microscope MAXYMUS at BESSY II, Berlin.

[1] M. Curcic et al., Phys. Rev. Lett. 101, 197204 (2008)
[2] S.-K. Kim et al., Appl. Phys. Lett. 92, 022509 (2008)

MA 38.4 Wed 15:30 HSZ 403

Pump-Probe SAXS experiments on ultrafast demagnetization of magnetic multilayers — B. Pfau[1], •S. Schaffert[1], J. Mohanty[1], J. Geilhufe[1], F. Büttner[1,2], S. Flewett[1], L. Müller[3], C. Gutt[3], A. Al-Shemmary[3], S. Düsterer[3], H. Redlin[3], G. Grübel[3], B. Vodungbo[4], J. Lüning[5], D. Stickler[6], R. Frömter[6], H.P. Oepen[6], W.F. Schlotter[7], and S. Eisebitt[1] — [1]IOAP, Technische Universität Berlin, Germany — [2]Paul Scherrer Institut, Villigen, Switzerland — [3]HASYLAB at DESY, Hamburg, Germany — [4]ENSTA ParisTech - Ecole polytechnique, Palaiseau, France — [5]Université Pierre et Marie Curie, Paris, France — [6]Universität Hamburg, Germany — [7]LCLS at SLAC, Menlo Park, USA

We have investigated the ultrafast optical demagnetization of domain patterns in magnetic multilayers with perpendicular magnetic anisotropy in an infrared-pump x-ray-probe experiment. As a probe we used small angle x-ray scattering which, via x-ray magnetic circular dichroism at the Co M-edge, allows us to simultaneously obtain information on the magnitude of the local magnetization and the characteristic length scale of the magnetic domains. The free-electron laser source FLASH at Hamburg was tuned to deliver $\lambda = 20.9$nm x-ray pulses of approx. 25 fs duration which were synchronized to an infrared fs laser for pump-probe experiments with sub-ps time resolution. In addition to ultrafast demagnetization, we observe sub-ps structural changes of the magnetic domain configuration. Models to explain this ultrafast structural change will be discussed.

MA 38.5 Wed 15:45 HSZ 403

Ultrafast Element-Specific Decoupling of Magnetization Dynamics in Permalloy — •Patrik Grychtol[1,3], Chan La-O-Vorakiat[1], Stefan Mathias[1,2], Justin Shaw[4], Roman Adam[3], Hans Nembach[4], Mark Siemens[1], Steffen Eich[2], Henry Kapteyn[1], Margaret Murnane[1], Claus M. Schneider[3], Tom Silva[4], and Martin Aeschlimann[2] — [1]Department of Physics and JILA, University of Colorado, Boulder, Colorado 80309-0440, USA — [2]University of Kaiserslautern and Research Center OPTIMAS, 67663, Kaiserslautern, Germany — [3]Institute of Solid State Research, IFF-9, Research Center Juelich, 52425, Juelich, Germany — [4]Electromagnetics Division, National Institute of Standards and Technology, Boulder, Colorado 80305-3328, USA

Elucidating the dynamic behavior of complex magnetic systems far from their thermal equilibrium is a topic of utmost scientific interest. In our work, we employ soft x-ray pulses from high-harmonic-generation to probe the dynamic response of thin permalloy films during an ultrafast optically driven demagnetization process [1]. We find that the demagnetization times for the elements Fe and Ni differ significantly, despite their strong exchange coupling in the thermodynamic equilibrium. We ascribe this difference to a breakdown of exchange interaction on the femtosecond timescale, a process that we further enhance by alloying permalloy with Cu. Our data shows that, in general, a site-specific spin environment must be considered to correctly describe ultrafast magnetization processes in compounds.

[1] La-O-Vorakiat *et al.*, Phys. Rev. Lett. **103**, 257402 (2009)

MA 38.6 Wed 16:00 HSZ 403

The Driving Force of Ultrafast Demagnetization Dynamics — •Benedikt Müller, Mirko Cinchetti, Tobias Roth, Martin Aeschlimann, and Bärbel Rethfeld — University of Kaiserslautern, Germany

Irradiating a ferromagnetic material with an ultrashort laser pulse leads to a demagnetization process on a femtosecond timescale. Elliott-Yafet type scattering is one of the most invoked spin-flip mechanisms to give a microscopic description of such behavior. In particular, electron-

electron (el-el) [1] and electron-phonon (el-ph) [2] spin-flip scattering have been considered. We combined the basic ingredients of those two models. In the framework of a spin-resolved Boltzmann equation [3] this allows us to evaluate the relative importance of Elliott-Yafet-type spin-flip scattering and to identify the driving force for ultrafast demagnetization: The equilibration of temperatures and chemical potentials of the introduced spin-up and spin-down electronic systems.

[1] M. Krauss et al., Phys. Ref. B **80**, 180407 (2009)
[2] B. Koopmans et al., Nature Materials **9**, 3 (2010)
[3] B. Rethfeld et al., Phys. Ref. B **65**, 214303 (2002)

MA 38.7 Wed 16:15 HSZ 403

Distinct Demagnetization Dynamics of Ni and Fe Magnetic Moments in a NiFe Alloy — •Andrea Eschenlohr[1], Ilie Radu[1,2], Christian Stamm[1], Niko Pontius[1], Torsten Kachel[1], Florin Radu[1], Theo Rasing[2], and Alexey V. Kimel[2] — [1]Helmholtz Zentrum Berlin für Materialien und Energie, Elektronenspeicherring BESSY II, Albert-Einstein-Str. 15, 12489 Berlin — [2]Radboud University Nijmegen, Heijendaalseweg 135, 6525 AJ Nijmegen, The Netherlands

Ultrafast demagnetization has been approached from a variety of experimental and theoretical angles since the first observation of a subpicosecond quenching of magnetization in Ni [1]. Time constants of demagnetization have been established for elementary transition metals and rare earths. Their compounds and alloys, which are highly relevant for technological applications and for research into the microscopic origins of ultrafast demagnetization, are increasingly investigated with methods like TR-MOKE. Yet experimental methods which combine femtosecond time resolution with an element-sensitive measurement of the magnetization have so far been sparse. We bridge this gap by probing magnetization dynamics in ferromagnetic NiFe alloys in an element-resolved way with 100 fs x-ray pulses generated by the Femtoslicing facility at BESSY II via XMCD. We find different demagnetization time constants for Ni (80 +/- 30 fs) and Fe (240 +/- 30 fs) in Ni50Fe50, evidence of a decoupling of the Ni and Fe dynamics on ultrafast timescales despite the exchange interaction between the two elements. [1] E. Beaurepaire et al., Phys. Rev. Lett. 76, 4250 (1996).

MA 38.8 Wed 16:30 HSZ 403

Relating Gilbert damping and ultrafast laser-induced demagnetization — •Christian Illg, Jonas Seib, and Manfred Fähnle — Max-Planck-Institut für Metallforschung, Heisenbergstraße 3, 70569 Stuttgart

Two regimes of short-time magnetization dynamics are usually distinguished: First, the dynamics on a time scale of nanoseconds to several picoseconds driven by external magnetic fields or by spin-polarized electrical currents. Second, the dynamics on a time scale of few picoseconds to subpicoseconds when exposing a thin film of Ni, Fe, or Co, e.g., to an optical femtosecond laser pulse. The first regime can be modelled by the Gilbert equation and the second by the Elliott-Yafet relation. There is a great interest to relate these two regimes.

In this talk a relation is established between the conductivity-like contribution to the Gilbert damping α at low temperatures and the demagnetization time τ_M for the ultrafast laser-induced demagnetization at low laser fluences [1]. It is assumed that the same types of spin-dependent electron-scattering processes are relevant for α and τ_M. The relation contains information on the properties of single-electron states which are calculated by the *ab initio* electron theory. The predicted value for α/τ_M is in good agreement with the experimental value.

[1] M. Fähnle, J. Seib, and C. Illg, Phys. Rev. B **82**, 144405 (2010)

MA 38.9 Wed 16:45 HSZ 403

Ultrafast Demagnetization Dynamics in $Ni_{1-x}Pd_x$ alloys — •Moritz Plötzing[1], Patrik Grychtol[1], Dennis Lvovsky[1], Roman Adam[1], Claus M. Schneider[1], Hans Nembach[2], Justin Shaw[2], Tom Silva[2], Daniel Steil[3], Mirko Cinchetti[3], and Martin Aeschlimann[3] — [1]Institute of Solid State Research, IFF-9, Research Center Jülich, 52425, Jülich, Germany — [2]Electromagnetics Division, National Institute of Standards and Technology, Boulder, Colorado 80305-3328, USA — [3]University of Kaiserslautern and Research Center OPTIMAS, 67663, Kaiserslautern, Germany

In our study we systematically investigate the ultrafast demagnetization process of alloys based on Ni and Pd induced by intense laser pulses in the femtosecond range. To this end, we fabricated samples by thermal co-evaporation of the respective elements over a wide range of $Ni_{1-x}Pd_x$ stoichiometries. We characterized all samples by measurements of the ferromagnetic resonance to determine the Gilbert damping parameter α as well as by measurements of the critical temperature T_c in a vibrating sample magnetometer. In time-resolved pump-probe experiments, exploiting the magneto-optical Kerr effect, we measured the demagnetization time τ_M for different $Ni_{1-x}Pd_x$ samples. Our contribution presents detailed experimental analysis of the relation of τ_M to α and T_c compared to the theoretical predictions as presented in [1].

[1] Koopmans et al., Phys. Rev. Lett. 95, 267207 (2005)

MA 38.10 Wed 17:00 HSZ 403

Understanding demagnetization dynamics in the Heusler alloy $Co_2Mn_{1-x}Fe_xSi$ — •Daniel Steil[1], Sabine Alebrand[1], Tobias Roth[1], Michael Krauss[1], Takahide Kubota[2], Mikihiko Oogane[2], Yasuo Ando[2], Hans Christian Schneider[1], Martin Aeschlimann[1], and Mirko Cinchetti[1] — [1]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67653 Kaiserslautern, Germany — [2]Department of Applied Physics, Graduate School of Engineering, Tohoku University, Sendai 980-8579, Japan

We have investigated ultrafast demagnetization in the half-metallic Heusler alloy system $Co_2Mn_{1-x}Fe_xSi$ (CMFS). The two investigated compounds CMS and CFS are predicted to be half metallic [1], with a different lineup of the minority band gap and the Fermi level. In CMS, the Fermi energy is lined up to the top of the valence band, while in CFS to the bottom. Despite such differences, both alloys show remarkably similar magnetization dynamics, as measured by the time-resolved magneto optical Kerr effect. Based on the experimental observations and our recent dynamical model that includes momentum- and spin-dependent carrier scattering [2], we show that magnetization dynamics are dominated by hole spin flips below the Fermi energy, which are not influenced by the band gap [3].

[1] B. Balke *et al.*, Phys. Rev. B **74**, 104405 (2006)
[2] M. Krauß *et al.*, Phys. Rev. B **80**, 180407 (2009)
[3] D. Steil *et al.*, Phys. Rev. Lett. **105**, 217202 (2010)