MA 34: Magnetization / Demagnetization Dynamics III

Time: Wednesday 15:00–18:45 Location: H 1012

MA 34.1 Wed 15:00 H 1012

Magnetic vortex core reversal by excitation of spin waves — •Hermann Stoll[1], Matthias Kammerer[1], Markus Weigand[1], Michael Curcic[1], Matthias Noske[1], Markus Sproll[1], Arne Vansteenkiste[2], Bartel Van Waeyenberge[2], Georg Woltersdorf[3], Christian H. Back[3], and Gisela Schütz[1] — [1]MPI for Intelligent Systems, Stuttgart (formerly MPI for Metals Research) — [2]Department of Solid State Science, Ghent University, Belgium — [3]Department of Physics, Regensburg University

Vortex structures possess azimuthal spin wave modes showing much higher eigenfrequencies than the vortex gyromode. Recently we could image by time-resolved scanning transmission X-ray microscopy vortex core reversal by exciting spin wave eigenmodes with rotating multi-GHz magnetic fields [1], much faster than by excitation of the sub-GHz vortex gyromode as demonstrated before. The vortex core polarization can be switched unidirectionally, either to up or down, as excitation only takes place when the sense of rotation of the external field and the spin wave mode are the same. These experimental results are in good agreement with our micromagnetic simulations [1], which clearly show: (i) the selection rules for this vortex core reversal process, (ii) the creation of a VA pair which is also essential for spin wave mediated vortex core reversal, (iii) asymmetries in vortex - spin wave interaction, caused by the gyrofield of the moving vortex, when spin waves with opposite rotation senses are excited. Limitations of the switching times for spin wave mediated vortex core reversal will be discussed.

[1] M. Kammerer et al., Nature Communications 2, 279 (2011)

MA 34.2 Wed 15:15 H 1012

Switching the magnetic vortex core by combined gyromode and spin wave excitation. — •Markus Sproll[1], Matthias Kammerer[1], Markus Weigand[1], Matthias Noske[1], Ajay Gangwar[2], Georg Woltersdorf[2], Hermann Stoll[1], and Gisela Schütz[1] — [1]MPI for Intelligent Systems, Stuttgart — [2]Department of Physics, Regensburg University

The vortex core (VC) in micron sized Permalloy platelets can be switched by exciting (i) the sub-GHz vortex gyromode [1] or (ii) multi-GHz azimuthal spin wave modes [2]. We have combined these two excitation schemes at significantly different frequencies and it was found that the switching threshold (i.e., the amplitude of the GHz rotating in-plane magnetic field) needed for spin wave mediated VC reversal is reduced by up to 30 % depending on the amplitude of an additional linear in-plane ac magnetic field at the sub-GHz gyromode eigenfrequency. Experiments have been performed by time-resolved measurements at the MAXYMUS (STXM) endstation at BESSY. Movies have been taken, starting with the excitation of the VC by a gyrotropic vortex gyration before a CW or CCW rotating spin wave mode was excited simultaneously with the gyromode. Finally only the VC gyration is excited again showing in case of polarity switching by the spin wave a reversed sense of rotation. All these experimental findings are in good agreement with micromagnetic simulations. A physical explanation for the reduced switching thresholds will be discussed as well as spintronic applications. [1] B. Van Waeyenberge et al., Nature 444, 461(2006) [2] M. Kammerer et al., Nature Communications 2, 279(2011)

MA 34.3 Wed 15:30 H 1012

Vortex core reversal by pulsed orthogonal magnetic fields of 100 ps duration and below — •Matthias Noske[1], Markus Weigand[1], Matthias Kammerer[1], Markus Sproll[1], Ajay Gangwar[2], Hermann Stoll[1], Georg Woltersdorf[2], and Gisela Schütz[1] — [1]MPI for Intelligent Systems, Stuttgart — [2]Department of Physics, Regensburg University

Recently it was demonstrated that the magnetic vortex core can be unidirectionally switched by exciting azimuthal spin wave modes at frequencies in the multi-GHz range [1]. Compared to core reversal by using the sub-GHz vortex gyromode [2], the increased excitation frequencies allow for shorter switching times. In the present talk we will demonstrate how to speed up spin wave mediated vortex core reversal down to 100 ps by applying pulsed orthogonal magnetic fields. Experiments have been performed by time-resolved scanning transmission X-ray microscopy at the MAXYMUS endstation at BESSY II, Berlin. At micron sized Permalloy discs unidirectional vortex core switching could be achieved at an excitation time of 135 ps. On smaller samples switching was achieved at 105 ps excitation time, but in this case the vortex core reversal was found not to be unidirectional. The experimental findings correspond to our micromagnetic simulations which show a strong dependence on sample geometry. In addition, our simulations indicate that unidirectional vortex core reversal will be feasible at excitation times of less than 100 ps for certain sample geometries.

[1] M. Kammerer et al., Nature Communications 2, 279 (2011)
[2] B. Van Waeyenberge et al., Nature 444, 461 (2006)

MA 34.4 Wed 15:45 H 1012

Ultrafast switching of ferrimagnets — Sönke Wienholdt[1], Denise Hinzke[1], Peter Openeer[2], and •Ulrich Nowak[1] — [1]Universität Konstanz, 78457 Konstanz, Germany — [2]Uppsala University, 75120 Uppsala, Sweden

The ultrafast manipulation of magnetisation by fs laser pulses promises to become a real alternative to conventional techniques based on magnetic fields. It was demonstrated that a 80 fs, circularly polarised laser pulse is able to reverse magnetisation on a ps time scale, as if it acts as a short magnetic field pulse caused by the inverse Faraday effect [1]. In single-shot time-resolved imaging of magnetic structures [2] it has been shown that the magnetisation reverses via a linear pathway [3] without any precession. Even with linearly polarized light switching was demonstrated recently [4], probably on a purely thermal basis. These new types of switching have been demonstrated only in ferrimagnetic materials like GdFeCo, probably because of the antiferromagnetic coupling of the two different sub-lattices in these materials, leading to completely different dynamics as compared to a ferromagnet. To understand this new type of dynamics we perform atomistic spin model simulations of ferrimagnets and investigate their switching mechanisms in detail.

[1] C. D. Stanciu et al., Phys. Rev. Lett. **99**, 047601 (2007). [2] K. Vahaplar et al., Phys. Rev. Lett. **103**, 117201 (2009) [3] N. Kazantseva et al., Europhys. Lett. **86**, 27006 (2009) [4] I. Radu et al., Nature **472**, 205 (2011)

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MA 34.5 Wed 16:00 H 1012

Electron- and phonon-mediated ultrafast magnetization dynamics of Gd — •M. Sultan[1,2,3], A. Melnikov[2,4], U. Atxitia[5], O. C. Fesenko[5], and U. Bovensiepen[1] — [1]Fakult. Phys., Uni. Duisburg-Essen — [2]Fach. Phys., Freie Uni. Berlin — [3]National Cent. Phys., Islamabad — [4]Phys. Chem., FHI, Berlin — [5]Inst. Cienc. Mater., Madrid

Disentangling different microscopic contributions in ultrafast magnetization dynamics is a challenging task. As a potential system to resolve this, Gd exhibits a two step demagnetization with characteristic time scales of 0.75 ps and 40 ps related to the non-equilibrium and a quasi-equilibrium regimes, respectively [1]. Here we report on the temperature dependent ultrafast magnetization dynamics of Gd(0001), which was investigated by employing the fs time-resolved magneto-optical Kerr effect and modelling by the Landau-Lifshitz-Bloch equation. The demagnetization time determined from the experiment increases with temperature from 0.8 ps at 50 K to 1.5 ps at 280 K. A successful theoretical description of this observation was achieved by considering that the localized 4f spin system is affected by two contributions: coupling to the 5d fraction through (a) electronic scattering processes and (b) spin-flip scattering mediated by phonons. We conclude that at temperatures below the Debye temperature a hot electron-mediated process describes the experimentally found demagnetization times well. At higher temperatures phonon-mediated processes have to be included in addition to explain the two times longer demagnetization time.

[1] Wietstruk et al., PRL 106, 127401 (2011)

MA 34.6 Wed 16:15 H 1012

Fs-time and momentum resolved resonant magnetic x-ray scattering on EuTe — •Christoph Trabant[1,2], Niko Pontius[2], Enrico Schierle[2], Eugen Weschke[2], Torsten Kachel[2], Rolf Mitzner[2], Christian Schüssler-Langeheine[2,1], Günther Springholz[3], and Karsten Holldack[2] — [1]II. Physikalisches Institut, Universität zu Köln — [2]G-I2/M-I1, Helmholtz-Zentrum Berlin — [3]Institut für Halbleiterphysik, Johannes Kepler Universität, Linz,Austria

Antiferromagnetic (AFM) materials have been discussed to provide special conditions for ultrafast magnetization dynamics since no macroscopic magnetization exists and dynamics might not be restricted by conservation of angular momentum. EuTe is a prototype AFM semiconductor (2.2eV band-gap). The AFM order results from competing exchange interactions between nearest-neighbors (FM coupling) and next-nearest-neighbors (AFM coupling) Eu^{2+}ions, which sensitively depend on the ion distances. The AFM order is detectable by a $(\frac{1}{2}\frac{1}{2}\frac{1}{2})$ superstructure reflection by resonant soft x-ray diffraction (RSXD).
We investigate the photoinduced magnetic dynamics on the fs- and ps-time-scale for different sample compositions. By recording time resolved q-scans we find that the thin film magnetic profile is modified in a completely different way than for elevated temperatures in thermal equilibrium. The measurements have been performed at the FEMTOSPEX facility at BESSY II.

MA 34.7 Wed 16:30 H 1012

Laser induced heating of thin nickel films investigated by time-resolved electron diffraction — •Carla Streubühr, Thorsten Brazda, Ping Zhou, Dietrich von der Linde, and Uwe Bovensiepen — Universtität Duisburg-Essen, Germany

Recently phonon excitation was reported to play an essential role in the ultrafast demagnetization of ferromagnetic materials [1]. Therefore information on the dynamics of lattice heating in magnetic materials is desired. Here we report on ultrafast lattice heating of thin crystalline nickel films at room temperature which were analyzed by time-resolved electron diffraction after femtosecond laser excitation.

Similar to the experiments on polycrystalline Ni [2], Au, Ag and Cu films [3] we observed an intensity decrease of the various diffraction spots after laser excitation. The relation of the intensity changes of different orders is interpreted as a rise in lattice temperature according to the Debye-Waller Effect. The heat capacity of nickel can no longer be treated as constant because of its high Debye temperature which leads to differences to the experiments on noble metals. We obtained a lattice temperature increase of about 160 K with a time constant of (1.5 ± 0.4) ps after exciting the sample by a fluence of about 5 $\frac{mJ}{cm^2}$ at a wavelength of 800 nm. In contrast to this the demagnetization of nickel on a silicon substrate is reported to have a time constant of 0.16 ps [1].

[1] B. Koopmans et al, Nature Materials **9**, 259 (2010)
[2] X. Wang et al, PRB **81**, 220301 (2010)
[3] M. Ligges et al, APL **94**, 1019410 (2009)

15 min. break

MA 34.8 Wed 17:00 H 1012

Gilbert damping parameter for transition metals and alloys at finite temperature: first-pinciples calculations — •S. Mankovsky, D. Koedderitzsch, and H. Ebert — Dept. Chemie/Phys. Chemie, Universität München, Butenandtstr. 11, D-81377 München, Germany

We present the results of calculations of the Gilbert damping parameter α for pure 3d transition metals as well as for disordered alloys containing magnetic 3d elements. The calculations of the α parameter were performed within the linear response formalism via the KKR Green's function band structure method. The role of various influences on the Gilbert damping have been investigated: chemical composition, crystal lattice structure, spin-orbit coupling of the elements and temperature. In particular, we focus here on the finite temperature dependence of the Gilbert damping, caused by temperature induced structural and magnetic disorder in the system. These scattering mechanisms have been accounted for by means of the alloy analogy scheme using the coherent potential approximation (CPA) alloy theory. The effects of structural and magnetic disorder are accounted for separately as well as simultaneously, to see their interrelation in pure materials as well as in the presence of impurities. The theoretical results for the Gilbert damping parameters are compared with available experimental data.

MA 34.9 Wed 17:15 H 1012

Accessing the timescale of indirect exchange interaction in GdTb alloy by time-resolved x-ray spectroscopy — •Andrea Eschenlohr[1], Alexey Melnikov[2], Jens Wieczorek[3], Nicolas Bergeard[3], Christian Stamm[1], Torsten Kachel[1], Rolf Mitzner[1], Karsten Holldack[1], Marko Wietstruk[4], Kristian Döbrich[4], Martin Weinelt[4,5], and Uwe Bovensiepen[3] — [1]Helmholtz Zentrum Berlin für Materialien und Energie GmbH — [2]Fritz-Haber-Institut der Max-Planck-Gesellschaft, Berlin — [3]Universität Duisburg-Essen — [4]Max-Born-Institut für Nichtlineare Optik und Kurzzeitspektroskopie, Berlin — [5]Freie Universität Berlin

Time-resolved x-ray magnetic circular dichroism measurements on pure Gd and Tb show two-step demagnetization upon laser excitation [1], with different time constants for the second, slower process. In particular, this time constants depend on the strength of spin-lattice coupling, leading to a faster demagnetization in Tb, due to strong direct spin-lattice coupling, than in Gd. Here we investigate GdTb alloy, where the Gd 4f magnetic moments are coupled to the Tb 4f moments via indirect exchange interaction, resulting in an enhanced coupling of the Gd moments to the lattice. Indeed, we find that the Gd magnetic moments in GdTb alloy demagnetize faster than pure Gd. Looking at the element-specific magnetization dynamics on the femtosecond to picosecond timescale, we access the timescale of indirect exchange interaction between Gd and Tb magnetic moments in the alloy.

[1] M. Wietstruk et al., Phys. Rev. Lett. 106, 127401 (2011)

MA 34.10 Wed 17:30 H 1012

Precessional dynamics and damping in Co/Cu/Py spin valves — •Ruslan Salikhov[1], Radu Abrudan[1], Frank Brüssing[1], Stefan Buschhorn[1], Melanie Ewerlin[1], Durga Mishra[1], Florin Radu[2], Ilgiz A. Garifullin[3], and Hartmut Zabel[1] — [1]Ruhr-Universität Bochum, Germany — [2]Helmholtz-Zentrum Berlin, Germany — [3]Zavoisky Physical-Technical Institute, Kazan, Russia

We have studied Co/Cu/Py (where Py = Ni81Fe19) spin valve systems with different thicknesses of Cu-spacer layers (25 and 40 nm) using the Time-Resolved X-ray Resonant Magnetic Scattering at the synchrotron radiation facility BESSY II of the HZB. This method enables the detection of the free precessional decay of the magnetization of ferromagnetic (F) films in response to a field pulse excitation [St. Buschhorn, et. al., J. Phys. D 44, 165001 (2011)]. We have found that the magnetic precessional decay time of Fe magnetic moments in Py layers decreases when changing the mutual orientation of the magnetization direction of Py and Co layers from parallel (P) to antiparallel (AP). Taking into account all possible mechanisms which can cause the observed effect in our samples where the exchange interaction between F-layers is negligible, we suppose that the increase of damping for AP orientation of magnetizations is associated with the spin-pumping-induced damping effect. The observed orientational dependence of the damping of free F-layer in the spin valves due to spin pumping was predicted theoretically by Kim and Chappert [J.-V. Kim, C. Chappert, JMMM 286, 56 (2005)] and until now there was no experimental evidence for this effect in the literature.

MA 34.11 Wed 17:45 H 1012

Small damping constant for Ni/Co multilayers with perpendicular magnetic anisotropy — •Markus Härtinger[1], Christian H. Back[1], See-Hun Yang[2], Stuart S. P. Parkin[2], and Georg Woltersdorf[1] — [1]Department of Physics, Universität Regensburg, 93040 Regensburg, Germany — [2]IBM Almaden, San Jose, U.S.A.

It is known, that perpendicular magnetic anisotropy exists in materials which consist of multilayers comprised of alternating ultrathin layers of Co separated by ultrathin layers especially of Pt, Pd or Ni. In these systems the perpendicular magnetic anisotropy field can be sufficiently large to overcome the shape anisotropy and induces a magnetic easy axis perpendicular to the multilayers.

We study the static and dynamic properties of magnetic multilayers composed of alternating ultrathin layers of Co and Ni. In particular, the evolution of perpendicular magnetic anisotropy and the Gilbert damping parameter is investigated as a function of thickness using ferromagnetic resonance. We find a rather small Gilbert damping constant $\alpha = 0.014$. In addition we recognize only a weak dependence of the magnetic properties of the number of multilayer repetitions.

MA 34.12 Wed 18:00 H 1012

Micromagnetic simulation of spin wave mediated synchronization between two pointcontact spin torque nanooscillators — •Thomas Kendziorczyk and Tilmann Kuhn — Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster

It has been predicted theoretically and observed experimentally that a direct current traversing a magnetic multilayer exerts a spin torque on the magnetic system which can compensate the natural damping and lead to magnetic autooscillations in the GHz range. Due to the easy frequency tunability and the narrow linewidth of the spin torque nanooscillators (STNOs) this effect has great potential for the construction of nanosized microwave generators. The main problem which has to be solved for future applications is the low output power of a single STNO. In order to construct larger arrays of STNOs a good knowledge about the coupling mechanism between them is indispensable. We have performed micromagnetic simulations based on the Landau-Lifshitz equation including dipolar and exchange interactions with a supplementary spin torque transfer term. We will show that the STNOs can synchronize mutually due to exchange of spin waves and oscillate coherently with the same frequency. The phase difference and spatial coherence of the STNOs depend on the distance between them and differences in their size. These results can be explained by means of a simple model of two coupled differential equations describing nonlinear autooscillators.

MA 34.13 Wed 18:15 H 1012

Quantum mechanical contribution to the magnon dispersion in the Heisenberg model — •Julian Hüser and Tilmann Kuhn — Institut für Festkörpertheorie, Universität Münster, Wilhelm-Klemm-Str. 10, 48149 Münster

The main contributions to the magnon dispersion in thin magnetic films are provided by the exchange and dipole-dipole interactions. Most fundamental work is based on the Heisenberg model which is able to explain this complex dispersion relation. It has been shown by several authors that by making the transition to classical spins a dispersion relation is obtained which is equal to the result of the harmonic spinwave approximation by applying either the Holstein-Primakoff or the Dyson-Maleev transformation. Because of the nonlinearity of these boson mappings higher-order terms which are omitted in the harmonic spinwave approximation react on the linear terms and thus modify the dispersion relation. Therefore, this modification is a purely quantum mechanical effect. However, this correction has mostly been neglected so far and barely investigations were made to confirm the validity of the harmonic spinwave approximation. The present work provides an analysis of this quantum mechanical effect and shows in which cases it is negligible or not.

MA 34.14 Wed 18:30 H 1012

Photo-magnonics: Influence of antidot-lattice symmetry on spin-wave Bloch states — •Benjamin Lenk, Nils Abeling, Jelena Panke, and Markus Münzenberg — I. Physikalisches Institut, Georg-August-Universität Göttingen

Femtosecond laser pulses are used to optically excite (pump) and subsequently measure (probe) magnetization dynamics on thin (50 nm) CoFeB films. On timescales as long as nanoseconds spin waves are observed that can be manipulated with periodic structures. In our case, two-dimensional arrays of antidots provide a periodic "potential" to the excited spin waves which then propagate along selected directions of the lattice. On the way towards spin-wave logic devices an understanding of the respective mechanisms for magnonic manipulation is of crucial importance. The structured CoFeB films show magnonic modes with Bloch-like character. Their dispersion $\omega(H_{\text{ext}})$ is used to determine the wave vector which turns out to be π/a, where a is the lattice parameter of the antidot structure. It is shown that the propagation direction remains in nearest-neighbor direction even if the structure's symmetry changes. Moreover, hexagonal lattices yield the possibility to tune the wave vector to $\pi/2a$.

In our contribution, we focus on the influence of the symmetry and prove the population of spin-wave Bloch states at the Brillouin zone boundary. These findings together with the low intrinsic damping of the material under consideration provide the basis for propagation experiments on antidot waveguides, first corresponding results are presented.