MA 30: Spin-Dynamics / Spin-Torque III

Time: Thursday 10:15–13:00 Location: HSZ 04

MA 30.1 Thu 10:15 HSZ 04

Current and Field Induced Domain-Wall Motion in Permalloy Nanowires — •Gesche Nahrwold[1], Lars Bocklage[1], Toru Matsuyama[1], Jan M. Scholtyssek[1], Benjamin Krüger[2], Ulrich Merkt[1], and Guido Meier[1] — [1]Universität Hamburg, Jungiusstr. 11, 20355 Hamburg — [2]Universität Hamburg, Jungiusstr. 9, 20355 Hamburg

Magnetic domain walls (DWs) in nanowires have attracted a lot of interest because of their possible application in logic and memory devices [1]. We present results obtained in curved permalloy wires where DWs are pushed by ns current pulses. By an externally applied magnetic field the DW is generated in the curved region of the wire. Measurements of the anisotropic magnetoresistance verify the presence of the wall. The resistance values before and after a current pulse indicate whether the DW has been depinned and moved out of the wire or not. Motivated by the pioneering work of L. Thomas et al. [2] we are able to measure the oscillatory dependence of the depinning behaviour of DWs on the pulse length with a characteristic frequency of 267 MHz if the current induced force on the DW is aligned opposite to the applied background field. The quality of the utilized permalloy for these experiments is crucial for their success. By sputtering permalloy on heated substrates we are able to considerably decrease the specific resistance, that is assumed to directly correspond to unwanted pinning centres for the DW. [1] S. S. P. Parkin et al., Science 320, 190 (2008), [2] L. Thomas et al., Nature 443, 197 (2006).

MA 30.2 Thu 10:30 HSZ 04

Non-adiabatic spin transfer torque in high anisotropy magnetic nanowires with narrow domain walls — •Jan Heinen, Olivier Boulle, Johannes Kimling, Mathias Kläui, and Ulrich Rüdiger — Fachbereich Physik, Universität Konstanz, Universitätsstrasse 10, 78457 Konstanz, Germany

The recent discovery that a spin polarized current can move a domain wall (DW) through a transfer of spin angular momentum opens a new path to manipulating magnetization without any external magnetic field. So far, current induced DW motion (CIDM) has been experimentally investigated in details for in-plane magnetized wires with a large DW widths ($\geq$ 100 nm) where spin transfer is expected to occur in the "adiabatic limit". Here, we report on current driven depinning experiments of a narrow ($\approx$ 6 nm) Bloch domain wall (DW) in perpendicularly magnetized $(Pt/Co)_3$ multilayer studied by magnetotransport. Such materials are ideal to tackle the key question of the non-adiabaticity of the spin transfer as a larger effect is expected due to the high DW magnetization gradient. We find that for conventional measurements, Joule heating effects conceal the real spin torque efficiency and so we use a measurement scheme at a constant sample temperature to unambiguously extract the spin torque contributions. From the variation of the depinning magnetic field with the current pulse amplitude, we directly deduce the large non-adiabaticity factor in this material and we find that its amplitude is consistent with momentum transfer [1].

[1] Boulle et al., Phys. Rev. Lett. 101, 216601 (2008).

MA 30.3 Thu 10:45 HSZ 04

Current-Induced Domain Wall Coupling and Domain Wall Motion in Magnetic Nanowires — •Nicholas Sedlmayr[1], Jamal Berakdar[1], and Vitalii Dugaev[2,3] — [1]Institut für Physik, Martin-Luther-Universität Halle-Wittenberg, Heinrich-Damerow-Str. 4, 06120, Halle, Deutschland — [2]Department of Physics, Rzeszów University of Technology, al. Powstańców Warszawy 6, 35-959 Rzeszów, Poland — [3]Department of Physics and CFIF, Instituto Superior Técnico, TU Lisbon, av. Rovisco Pais, 1049-001, Lisbon, Portugal

We consider the problem of two domain walls (DWs) inside a quasi-one dimensional magnetic nanowire. It is assumed that the distance between DWs is rather small so that the transmission of current results in the current-induced DW coupling. The primary cause of the current-induced interaction between the DWs is the spin torque transferred by the spin current to the second DW after the electrons are transmitted through the first one. The interaction between the two walls is investigated by studying the increased energy caused by scattering events from both walls. Calculating the interaction between the DWs, we found that the current-induced effective potential is oscillating in space, which leads to the oscillating motion of the DW. We go on to see what effect the scattering of current electrons from one wall has on the spin density and spin torque acting on the second domain wall. Assuming, for definiteness, that the first wall is pinned we investigate the motion of the second domain wall.

MA 30.4 Thu 11:00 HSZ 04

Time-Resolved Imaging and Modeling of Oscillations of a Single Magnetic Domain Wall — •Lars Bocklage[1], Benjamin Krüger[2], René Eiselt[1], Markus Bolte[1], Peter Fischer[3], and Guido Meier[1] — [1]Institut für Angewandte Physik, Universität Hamburg — [2]I. Institut für Theoretische Physik, Universität Hamburg — [3]Center for X-Ray Optics, Lawrence Berkeley National Laboratory, Berkeley, California

Current-induced magnetization dynamics are an intersting field of research. Domain walls and vortices can be moved by spin-polarized currents. We image oscillations of a single domain wall in a confining potential in time steps of 200 ps by time resolved x-ray microscopy with a spacial resolution of 25 nm and a temporal resoution of 70 ps [1]. The oscillation of the domain wall is triggered by nanosecond current pulses. The spin-polarized current and the accompanied Oersted field can contribute to the motion of the wall. An analytical model of a rigid particle precisely describes the domain-wall motion. From the observed oscillations we extract the confining potential, the driving force, the domain-wall mass, and the damping parameter of permalloy. Higher than harmonic terms determine the motion of the wall. By looking at various phase spaces the influence of these nonharmonic contributions are studied.

This work was supported by DOE BES, SFB 668 and GrK 1286.

[1] L. Bocklage, B. Krüger, R. Eiselt, M. Bolte, P. Fischer, and G. Meier, PRB 78, 180405(R) (2008)

MA 30.5 Thu 11:15 HSZ 04

Simulations of current-induced domain wall motion including temperature effects using the Landau-Lifshitz-Bloch equation — •Christine Schieback, Denise Hinzke, Mathias Kläui, Ulrich Rüdiger, Ulrich Nowak, and Peter Nielaba — Department of Physics, University of Konstanz, Germany

By numerically solving the stochastic Landau-Lifshitz-Gilbert (LLG) equation, computer simulations can be performed on a classical atomistic spin model. Spin torque effects can be taken into account by further inclusion of an adiabatic and a non-adiabatic torque term [1]. Due to the computational expense of atomistic simulations, system sizes are restricted to a nanometer range, so that micromagnetic approaches are desirable. However, conventional micromagnetic calculations for larger system sizes lack the correct description of temperature effects because of the assumption of a constant magnetisation length.

An alternative novel approach to investigate realistic systems sizes including temperature effects is to employ the so-called Landau-Lifshitz-Bloch (LLB) equation [2]. This equation forms a new basis for micromagnetic calculations at elevated temperatures using a macro spin model [3], where longitudinal relaxation processes are taken into account. We extend the LLB equation of motion by adding spin torque terms and study domain wall motion under the influence of current and temperature in permalloy films. Domain wall velocities show a strong temperature dependence.

[1] C. Schieback et al. EPJ B 59, 429 (2007). [2] D. A. Garanin PRB 55, 3050 (1997). [3] N. Kazantseva et al. PRB 77, 184428 (2008).

MA 30.6 Thu 11:30 HSZ 04

Correlation between the pinning behavior of domain walls (dw) and the edge roughness of etched GMR nanostrips — •Sascha Glathe, Marco Diegel, and Roland Mattheis — IPHT Jena, Albert-Einstein-Str. 9, 07745 Jena

During dw motion in nanostrips a dw samples the energy landscape, caused for example by edge roughness. As a result the dw can be pinned at local energy minima. The pinning and depinning process of dw in long GMR nanostrips (width = 160 nm, length = 200 000 nm) was examined using time resolved resistance measurements. We found many small fluctuation of the potential giving rise to weak dw pinning with thermally activated depinning. However there are some large pinning sites acting as deep potential wells for the dw. To get further inside in the pinning mechanism at these potential wells we examined the influence of a transversal field on the depinning fields and pinning probability and found significant dependencies.

MA 30.7 Thu 11:45 HSZ 04

Damping of the domain wall dynamics by phonon and magnon dragging — •Daniel Hähnel, Daniel Steiauf, and Manfred Fähnle — Max-Planck-Institut für Metallforschung, Heisenbergstr. 3, 70569 Stuttgart

The understanding of the damped domain-wall motion, especially in nanoparticles and nanowires, is of central interest for many technological applications. Commonly, the damping of the domain wall is discussed in terms of spin-lattice interactions via spin-orbit coupling. At finite temperatures, however, the movement of the domain walls is also hampered by phonon or magnon dragging, i.e., by transfer of momentum between thermally excited phonons or magnons and the moving domain wall. We present a theory which describes the phonon dragging due to the scattering of phonons at the magnetoelastic strain field of the moving domain wall. The numerical results for this phonon dragging are compared with those obtained for the magnon dragging of domain walls [1].

[1] H. Glock, PhD thesis, University of Stuttgart, 1974.

MA 30.8 Thu 12:00 HSZ 04

Tailoring the Gilbert damping coefficient in Permalloy thin films by Ho doping — •Jakob Walowski[1], Benjamin Lenk[1], Andreas Mann[1], Henning Ulrichs[1], Stephen Krzyk[2], Mathias Kläui[2], and Markus Münzenberg[1] — [1]Physikalisches Institut, Universität Göttingen, Germany — [2]Fachbereich Physik, Universität Konstanz, Gemany

The implementation of spintronics requires well-funded knowledge of the speed limits regarding magnetic switching. We use all-optical pump-probe experiments to explore the dynamics of 20 nm permalloy thin films triggered by strong Ti:Sa laser pulses ($30\,\mathrm{mJ/cm^2}, 60\,\mathrm{fs}$) on two timescales after demagnetization. The fast demagnetization after excitation within the first $100-250$ fs and the subsequent spin relaxation on a timescale up to 1 ns. It is generally described by the Landau-Lifshitz-Gilbert equation, from which the Gilbert damping parameter α can be extracted. Doping ferromagnetic materials with impurities in low concentrations can influence the intrinsic damping parameter ($\alpha(\mathrm{Py}) = 0.008$), as has been shown using transition metal (Pd) and rare earth impurities (Dy) in concentrations up to 2% in our group. Here we extend of our study, using the rare earth Ho as an impurity dopant. It shows a stronger increase of α, for the same percentage of dopant than Dy. According to the model by Koopmans, the demagnetization time should be inversely proportional to α which doen not necessarily have to agree for the Ho doped samples, because of different dissipation channels in the rare earth impurities. Support by the DFG within the priority program SPP 1133 is gratefully acknowledged.

MA 30.9 Thu 12:15 HSZ 04

Spin-wave excitation in Permalloy by oscillating pinned domain walls — •Sebastian Hermsdörfer, Helmut Schultheiss, Christopher Rausch, Sebastian Schäfer, Philipp Pirro, Britta Leven, and Burkard Hillebrands — Fachbereich Physik und Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

In this presentation a new mechanism for the spin-wave excitation will be presented. The excitation of spin waves by oscillating pinned domain walls is an alternative approach to the well-known excitation via an antenna or, as another example, via vortex-anti-vortex-annihilation. The investigations have been carried out using micromagnetic simulations. The basic idea of the mechanism is to deflect a pinned domain wall out of its equilibrium position within the limits of the domain wall pinning. The following relaxation caused by the pinning potential which is driving the wall back towards the equilibrium position occurs as a damped oscillation with characteristic eigenfrequency. In case that the domain wall is excited by an external field with this eigenfrequency, a "steady-state" oscillation forms out with the eigenfrequency and an amplitude determined by the energy balance between the dissipation processes due to damping and the external triggering by the applied field. The energy pumped into the system by the external field leads not only to the compensation of the damping but also to the radiation of spin waves.

Financial support by the DFG within the SPP1133 is gratefully acknowledged.

MA 30.10 Thu 12:30 HSZ 04

Lifetime of quantized spin waves in nano-scaled magnetic ring structures — •Helmut Schultheiss, Björn Obry, Christian Sandweg, Sebastian Hermsdörfer, Sebastian Schäfer, Thomas Sebastian, Britta Leven, and Burkard Hillebrands — Fachbereich Physik and Research Center OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany

The magnetization dynamics of rings, magnetized in the onion state, shows a rich eigenmode spectrum. Quantization of spin waves takes place not only due to the spatial confinement in radial and azimuthal directions, but also in spin-wave wells in the so-called pole regions created by the inhomogeneity of the internal magnetic field. To understand the dissipation mechanisms and coupling between different spin-wave modes, we have investigated the relaxation processes using time- and space-resolved Brillouin light scattering microscopy. The decay of the magnetization after excitation with a short microwave pulse was studied as a function of frequency and position. We have determined the decay constants of the spin-wave modes that can be excited with in-plane microwave pulses. The comparison of the dissipation times of the ring eigenmodes confined in the pole and equatorial regions, respectively, of the onion state indicates that different dissipation mechanisms are responsible for the relaxation of the magnetization, depending on the position and the quantization conditions of the spin-wave eigenmodes. Financial support by the DFG (SPP1133) is acknowledged.

MA 30.11 Thu 12:45 HSZ 04

Coupling of spin-wave eigenmodes in small magnetic ring structures — •Björn Obry[1], Helmut Schultheiss[1], Christian Sandweg[1], Sebastian J. Hermsdörfer[1], Sebastian Schäfer[1], Vasyl Tiberkevich[2], Britta Leven[1], Andrei N. Slavin[2], and Burkard Hillebrands[1] — [1]FB Physik and Forschungszentrum OPTIMAS, TU Kaiserslautern, 67663 Kaiserslautern, Germany — [2]Department of Physics, Oakland University, Rochester, MI, USA

Understanding the coupling of spin-wave eigenmodes in small magnetic structures is of great importance for future applications of those structures in technical devices. Measurements with time- and space-resolved Brillouin light scattering microscopy were performed on permalloy rings placed on top of a coplanar waveguide in order to excite spin waves by the Oersted field of a microwave current. The rings under investigation have outer diameters between 1 and 3 μm, ring widths of 100 to 400 nm and a thickness of 15 nm. Being magnetized in the onion state the rings reveal a direct coupling of spin-wave modes excited near the poles of the ring with modes confined to the equatorial region via three-magnon scattering processes. Excitation of spin waves confined only to the pole regions will result in the appearance of a spin-wave signal at the equators, if the frequency ratio between modes in the equatorial and pole regions is 2:1, fulfilling energy conservation for three-magnon scattering. The coupling turns out to be tunable by the external magnetic field and can be shown for rings of various diameters and widths. Financial support by the DFG (SPP1133) is acknowledged.