MA 18 Spin-Dynamics, Magnetization Reversal I

Time: Tuesday 10:15–13:00 Room: HSZ 403

MA 18.1 Tue 10:15 HSZ 403

Modal Spectrum of Permalloy Disks with and without Vortex — •Frank Hoffmann, Korbinian Perzlmaier, Georg Woltersdorf, Ingo Neudecker, and Christian Back — Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstrasse 31, 93040 Regensburg

The mode spectrum of micron-sized ferromagnetic permalloy disks, exhibiting a vortex ground state, was investigated. In equilibrium the magnetization is in the plane of the sample, except for a small region in the center, where it is aligned perpendicular.
Time resolved scanning Kerr microscopy was used to measure the temporal evolution of the magnetization after application of a fast rise time in-plane field pulse. Spatially resolved amplitude and phase spectra reveal the mode structure, that consists of modes with circular nodes and modes with diametric nodes.
It is shown, that the lowest order azimuthal mode, a mode with only one diametric node, splits into a doublet as the disk diameter decreases. Ivanov and Zaspel [1] have shown theoretically, that this splitting is due to interaction with the gyrotropic motion of the vortex core. By removing the vortex core the splitting of the modes vanishes. This behaviour was found both in micromagnetic simulations and experiments.
[1] PRL 94, 027205 (2005)

MA 18.2 Tue 10:30 HSZ 403

Microwave assisted switching in $Ni_{81}Fe_{19}$ — •P. Martin Pimentel, H.T. Nembach, S. Hermsdörfer, and B. Hillebrands — Fachbereich Physik and Forschungsschwerpunkt MINAS, TU Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663 Kaiserslautern, Germany

We present the study of the quasi-static switching behavior of a $Ni_{81}Fe_{19}$ ellipsoid under the influence of a microwave field by longitudinal magneto-optic Kerr effect magnetometry. The long axis of the ellipsoid is parallel to the quasi-static field in the plane of the element. The dimensions of the element are 160 μm x 80 μm x 10 nm. The switching behavior of the element is studied by measuring hysteresis curves with an applied microwave field perpendicular to the quasi-static magnetic field. The frequency of the microwave field was varied in the range of 500 MHz to 2.0 GHz in steps of 100 MHz and the microwave power is increased from -5 dBm to 35 dBm for each frequency. A strong reduction of the coercive field is observed for the microwave frequencies between 650 MHz to 900 MHz for the maximum output power of 35 dBm. This reduction can be described by two different mechanisms. The most important one is the enhancement of domain nucleation by the microwave field. The second, weaker mechanism is an enhanced growth of the reversed domain. This is due to the fundamental principle that every physical system favors the state with the lowest Gibbs free energy. We demonstrate that the switching process of elements, which is dominated by domain nucleation and propagation, can be stimulated by applying a transversal microwave field. This work is supported by the EU-RTN ULTRASWITCH (HPRN-CT-2002-00318).

MA 18.3 Tue 10:45 HSZ 403

Brillouin light scattering microscopy investigations of quantized spin waves in small magnetic ring structures — •H. Schultheiss[1], C. Bayer[1], H.T. Nembach[1], M.C. Weber[1], B. Leven[1], J. Podbielski[2], F. Giesen[2], D. Grundler[2], and B. Hillebrands[1] — [1]Fachbereich Physik und Forschungsschwerpunkt MINAS, TU Kaiserslautern, Erwin-Schrödinger-Str. 56, 67663 Kaiserslautern, Germany — [2]Institut für Angewandte Physik und Zentrum für Mikrostrukturforschung, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg, Germany

Spin wave quantization due to geometrical confinement and the presence of spin wave wells has been studied spatially and frequency resolved in mesoscopic magnetic ring structures. Brillouin light scattering microscopy with a spatial resolution of 300 nm allows for a local study of the spin dynamics within a single ring magnetized in the onion or the vortex state. The measured spin wave spectra do not change significantly along the ring in the vortex state, whereas in the onion state a strongly inhomogeneous internal field along the ring perimeter leads to different spin wave frequencies primarily in the pole and equatorial ring regions. Spin wave quantization in radial direction within the equatorial region of the onion state was found by comparing the experimental spectra with calculated spin wave dispersions. Moreover, effective spin wave wells caused by the inhomogeneous internal field distribution are responsible for spin wave localization in the pole region of the onion domain pattern. Hence, there is strong evidence for the coexistence of localized eigenmodes within a single microstructure due to two different quantization mechanisms.
Financial support by the DFG within the SPP 1133 and by the EC-RTN ULTRASWITCH is gratefully acknowledged.

MA 18.4 Tue 11:00 HSZ 403

Spatially resolved dynamic eigenmode spectrum of Co rings — •Ingo Neudecker[1], Mathias Kläui[2], Korbinian Perzlmaier[1], Dirk Backes[2,3], Laura J. Heyderman[3], Carlos A. F. Vaz[4], J. Anthony C. Bland[4], Ulrich Rüdiger[2], and Christian H. Back[1] — [1]Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Universitätsstrasse 31, D-93040 Regensburg, Germany — [2]Fachbereich Physik, Universität Konstanz, Universitätsstrasse 10, D-78457 Konstanz, Germany — [3]Paul Scherrer Institut, CH-5232 Villingen PSI, Switzerland — [4]Cavendish Laboratory, University of Cambridge, Madingley Road, Cambridge, CB3 0HE, United Kingdom

We determined the spatially resolved eigenmode spectrum of micrometer-sized Co ring magnets by means of vector network analyzer ferromagnetic resonance combined with time resolved magneto-optic Kerr effect measurements. In doing so up to five resonant eigenmodes were observed in the frequency range from 45 MHz to 20 GHz as a function of an external magnetic bias field. Well defined spatial modes were found both in the vortex and in the onion remanent states. The observed modes correspond to four longitudinal modes, with magnetostatic backward-volume character, and a transverse mode, localized in the transverse domain wall of the onion state. Finally the effect of inter-ring coupling on the modes in the remanent states was investigated. Good agreement between the experimental results and micromagnetic simulations was found. The study demonstrates that the ring representing a high symmetry structure exhibits simple eigenmode behavior.

MA 18.5 Tue 11:15 HSZ 403

Correlation of ferromagnetic precessional modes and domain wall density in patterned ferromagnetic films — •Ute Queitsch[1], Jeffrey McCord[1], Rudolf Schäfer[1], Ludwig Schultz[1], Karsten Rott[2], and Hubert Brückl[2] — [1]Leibniz Institut für Festkörper- und Werkstoffforschung (IFW), Helmholtzstrasse 20, 01069 Dresden — [2]Universität Bielefeld, Lehrstuhl für Dünne Schichten und Nanostrukturen, Universitätsstrasse 25, 33615 Bielefeld

Understanding the correlation between magnetic microstructure and hf-response of patterned soft magnetic thin films is crucial for hf applications. The hf response of arrays of $CoZrTa$ single and bi-layer thin film elements ($200\mu m \times 50\mu m \times 80nm$) was investigated by means of pulsed inductive microwave magnetometry and directly compared to the domain structure analyzed by time resolved wide field Kerr microscopy. Different domain states were preset by varying the magnetic field history. Characteristic changes in the hf response depending on the domain wall density were observed. Domain walls were found to have a lower permeability compared to freely rotatable regions, leading to an additional contribution to the acting anisotropy field which leads to a drastic rise in the dominating ferromagnetic resonance frequency of the film. The demagnetizing field of the 90°-closure domain walls causes different modes of excitation and relaxation. Domain wall movements during the dynamic remagnetization process cause frequency components in the 100 MHz range. Due to stray field coupling the bilayers show an irregular domain pattern without closure domains which leads to a strong reduction of the number of precessional modes and domain wall movements.

MA 18.6 Tue 11:30 HSZ 403

Fast Resonant Vortex Core Switching — •H. Stoll[1], A. Puzic[1], K.W. Chou[1], B. Van Waeyenberge[2], T. Tyliszczak[3], I. Neudecker[4], K. Rott[5], H. Brückl[6], D. Weiss[4], G. Reiss[5], C.H. Back[4], and G. Schütz[1] — [1]MPI for Metals Research, Stuttgart — [2]Ghent University — [3]LBNL, Berkeley, CA — [4]Regensburg University — [5]Bielefeld University — [6]ARCS, Nano System Technology, Vienna

New ways were developed to switch the out-of-plane polarization of vortex cores in micron-sized ferromagnetic vortex structures either (i) by altering the amplitude of an alternating magnetic field at a frequency close to the eigenfrequency of the gyrotropic vortex motion or (ii) by applying a short burst (e.g., one single period) of this resonant ac magnetic field. Switching of the vortex core corresponds to a change of the chirality or handedness of the vortex structure. Experiments were performed on 1 to 2 micron large, 50 nm thick Permalloy circles and squares located on a Cu stripline. The polarization of the vortex core was detected with a scanning transmission X-ray microscope (STXM, ALS, Berkeley) by monitoring the sense of rotation of the vortex motion [1]. Magnetic vortex cores have already been discussed as candidates for magnetic data storage, but for switching of the vortex core polarization large magnetic fields in the order of half a Tesla were required so far [2,3]. The resonant vortex core switching schemes presented here need much lower magnetic fields (in the order of 10 mT) and allow in addition high switching speeds.

[1] A. Puzic et al., J. Appl. Phys. 97, 10E704 (2005)
[2] T. Okuno et al., J. Appl. Phys. 95, 3612 (2004)
[3] A. Thiaville et al., Phys. Rev. B 67, 094410 (2003)

MA 18.7 Tue 11:45 HSZ 403

Spin wave logic gates — •T. Schneider, M. Kostylev, B. Leven, A. Serga, and B. Hillebrands — Fachbereich Physik, TU Kaiserslautern, 67663 Kaiserslautern

We present a new approach for magnetic logic gates either using the phase or the amplitude of the spin-waves. A XNOR gate has been realized using the spin-wave phase as logical “1” and “0”. The necessary phase-shifts can be realized by a weak, locally confined magnetic field, e.g. the field of a current carrying conductor. Using this current controlled phase shifter (CPS), the XNOR gate can be constructed as a Mach-Zehnder interferometer with a CPS in each of the branches. In addition, we have created a NAND gate using the spin-wave amplitude as logical signal. We demonstrate that by applying a magnetic field which is stronger than in the case of the XNOR gate the spin-wave amplitude can be suppressed thus realizing the required input negation. We have constructed prototypes of both logic gates based on yttrium-iron-garnet waveguides and we demonstrate the performance.

This work has been supported by the Deutsche Forschungsgemeinschaft and by the European Community within the EU-project MAGLOG (FP6-510993).

MA 18.8 Tue 12:00 HSZ 403

Ballistic Bit Addressing in a Magnetic Memory Cell Array — •Hans Werner Schumacher — Physikalisch-Technische Bundesanstalt, Bundesallee 100, 38116 Braunschweig

A ringing free bit addressing scheme for magnetic random access memories (MRAM) is proposed. As in standard MRAM addressing schemes the switching of a selected cell is obtained by the combination of two half-select field pulses. Numerical solutions of a single spin model of an MRAM cell show that the pulse parameters can be chosen such that the application of the half select pulse induces a full precessional turn of the magnetization (no switch) whereas the superposition of two half select pulses induces a half precessional turn (switch) [1]. With well adapted pulse parameters both full-select and half-select switching occurs on ballistic trajectories characterized by the absence of ringing after magnetic pulse decay. Such ballistic bit addressing allows ultra high MRAM write clock rates and a highly parallel write operation [2].

References: [1] H. W. Schumacher, Appl. Phys. Lett. 87, 042504 (2005). [2] H. W. Schumacher, J. Appl. Phys. 98, 033910 (2005).

MA 18.9 Tue 12:15 HSZ 403

Current assisted switching of magnetic tunneling cells with MgO barriers — •Guenter Reiss and Karsten Rott — Bielefeld University, Department of Physics, P.O. Box 100 131, 33501 Bielefeld, Germany

The CMOS and scaling compatibility of the magnetic switching of the soft electrode in magnetic tunneling junctions is one of the major challenges in the development of both Magnetic Random Access Memory as well as Field Programmable Logic Gate Arrays. Because the traditional method of switching by field pulses generated by current lines requires large currents and is not scalable, alternative schemes such as heat assisted switching have been porposed and demonstrated. Here, we show, that the spin torque of the spin polarized current driven through a magnetic tunneling junction with low resistive MgO barriers with a of TMR around 130% can both reduce considerably the apparent coercive field of the soft layer and is even capable of switching the magnetization of the soft electrode. The currents needed for switching are in the range of some mA per square micron and thus open a way for CMOS compatibility of ultrasmall tunneling junctions.

MA 18.10 Tue 12:30 HSZ 403

Precessional switching in arrays of iron nano-magnets. — •Fabrizio Porrati and Michael Huth — Physikalisches Institut, J. W. Goethe-Universität, Max-von-Laue-Strasse 1, 60438 Frankfurt am Main

We present a bit addressing scheme for magnetic ram based on the application of two successive unipolar field pulses. We employ micromagnetic simulations to study the switching behaviour of an isolated nanomagnet as function of the pulses length. We discuss the role of the dipolar interaction by varying the relative distance of memory cells in an array of nanomagnets.

MA 18.11 Tue 12:45 HSZ 403

Domain Wall generation and movement in narrow GMR lines — •Roland Mattheis, Marco Diegel, Uwe Huebner, Dominique Schmidt, and Hardy Koebe — Institute for Physical High Technology, A.-Einstein-Str. 9, D-07745 Jena

Well defined motion of domain walls in narrow lines offer chances for new magneto electronic applications like magnetic logic [1] or multiturn counters for automotive and automation applications [2]. To analyse the behaviour of the domain walls we investigate the generation and movement of the 180° domain walls in 10 and 20 nm thick Ni81Fe19 layers as a part of a GMR stack. The structures consist of 150 x 250 nm wide lines with and without a domain generator at one end of the 0.500 mm line. By measuring the time and magnetic field dependence of the resistance we determine the distribution of the magnetic field necessary for the generation of a domain wall and the field dependence of the domain wall movement (domain wall mobility). Pinning and depinning of the domain walls was used to characterize geometrical perfection of the used structures. \Zitat{1}{Allwood D. A., Xiong G., Cooke M. D., Faulkner C. C., Atkinson D., Vernier N. and Cowburn R. P., Science, 296 (2002) 2003} \Zitat{2}{M. Diegel, R. Mattheis, E. Halder, IEEE Trans. Magn. 40 (2004) 2655}