MA 19: Micro Magnetism / Computational Magnetism

Time: Wednesday 10:15–12:45 Location: HSZ 403

MA 19.1 Wed 10:15 HSZ 403

Quantized spin waves in ferromagnetic and antiferromagnetic systems with domain wall. — •Robert Wieser, Elena Y. Vedmedenko, and Roland Wiesendanger — Institute of Applied Physics and Microstructure Research Center Hamburg, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg

The understanding of the magnetization dynamics of nanosized magnets has been the aim of many recent experimental and theoretical studies. Micromagnetic simulations have become a powerful tool to study the static and dynamic processes. One interesting topic in this field are standing spin waves. We investigate standing spin waves in ferromagnetic and antiferromagnetic systems in the presence of a transverse 180° domain wall. To investigate the spin waves, we have performed simulations by solving the Landau-Lifshitz-Gilbert equation and calculated the time dependent power absorption. We compare the numerical results with analytical calculations to proof the applicability. Further we demonstrate the fundamental differences between ferromagnetic and antiferromagnetic spin wave solutions [1] and show new analytical formulas to describe spin waves in frustrated antiferromagnetic spin rings.

[1] R. Wieser, E. Y. Vedmedenko, R. Wiesendanger, Phys. Rev. Lett. **101**, 177202 (2008)

MA 19.2 Wed 10:30 HSZ 403

Proposal for a Standard Problem for Micromagnetic Simulations Including Spin-Transfer Torque — Massoud Najafi[1], •Benjamin Krüger[1], Stellan Bohlens[1], Matteo Franchin[2], Hans Fangohr[2], Markus Bolte[1], Antoine Vanhaverbeke[3], Rolf Allenspach[3], Ulrich Merkt[1], Daniela Pfannkuche[1], Dietmar Möller[1], and Guido Meier[1] — [1]Universität Hamburg, Hamburg, Germany — [2]University of Southampton, Southampton, United Kingdom — [3]IBM Zurich Research Laboratory, Rüschlikon, Switzerland

The spin-transfer torque between itinerant electrons and the magnetization in a ferromagnet is of fundamental interest for the applied physics community. To investigate the spin-transfer torque powerful simulation tools are mandatory. For a comparison of different simulation tools it is important to develop standard problems that can be simulated by different tools and allow us to easily verify the implementation. Previous standard problems do not include spin-transfer torque. We propose a micromagnetic standard problem, including the spin-transfer torque, that can be used for the validation and falsification of micromagnetic simulation tools. The work is based on the micromagnetic model extended with the spin-transfer torque terms proposed by Zhang and Li [1]. The suitability of the proposed problem as a standard problem is proven by numerical results from four different finite-difference-method and finite-element-method based simulation tools.

[1] S. Zhang and Z. Li, Phys. Rev. Lett. 93, 127204 (2004).

MA 19.3 Wed 10:45 HSZ 403

Nanostructured FePt/Fe composite particles for ultrahigh density magnetic recording — •Dagmar Goll, Gisela Schütz, and Helmut Kronmüller — MPI für Metallforschung, Stuttgart, Germany

Composite particles based on bilayers consisting of a magnetically hard and a magnetically soft layer are promising candidates for realizing the main conditions for ultrahigh density magnetic recording: Thermal stability of > 10 a, coercive fields of 1 - 1.5 T and switching times in the subns region. FePt/Fe composite particles are predestinated to fulfill these conditions if the microstructure is designed suitably. In particular the coercive field may be tailored either by varying the thickness of the soft layer or by manipulating the width of the phase boundary between the soft and the hard magnetic layer. Both methods have been investigated experimentally and by analytical and computational micromagnetism. It is shown that the thickness dependence of the coercive field follows a $1/d_{\mathrm{soft}}^{3/2}$ law (d_{soft}: thickness of the soft layer) for particles with lateral dimensions larger than the thickness of the particle and a $1/d_{\mathrm{soft}}$ law for particles where lateral dimensions and the particle thickness are comparable with each other.

MA 19.4 Wed 11:00 HSZ 403

IrMn: the role of the anisotropy for exchange bias — •Jerome Jackson[1], Ulrich Nowak[1], Laszlo Szunyogh[2], Bence Lazarovits[2,3], and Laszlo Udvardi[2] — [1]Fachbereich Physik, Universität Konstanz, Germany — [2]Department of Theoretical Physics, Budapest University of Technology and Economics, Hungary — [3]Research Institute for Solid State Physics and Optics, Hungarian Academy of Sciences, Hungary

We present ab-initio work concerning the anisotropy in the industrially significant antiferromagnet $IrMn_3$, and results of an atomistic spin model parametrised using ab-initio data[1]. In particular, we obtain the surprising result that the cubic crystal symmetry is locally broken, leading to a strong second order anisotropy, $K \approx 3 \times 10^8$ erg/cc. The easy axis is oriented along the three different (100) axes for each of the three sublattices in the $L1_2$ structure. This anisotropy structure is confirmed by ab-initio calculations and reproduces the experimentally observed ground state spin structure[2].

Using the spin model, the response of individual antiferromagnetic grains to the exchange field of a reversing ferromagnet have been investigated. For the case of the fully compensated (111) interface, we discuss the distortion of the "T1" ground state and the possibility of exchange bias at such interfaces; the stability and reversal mechanisms of $IrMn_3$ grains are also examined.

[1]L. Szunyogh, L. Udvardi *et.al. Phys. Rev. B, submitted* (2008)
[2]I. Tomeno, H.N. Fuke *et.al. J. Appl. Phys* 86 (1999) 3853

MA 19.5 Wed 11:15 HSZ 403

Micromagnetic structure in permalloy rectangles — Holger Stillrich, Sebastian Hankemeier, Nikolai Mikuszeit, Daniel Stickler, Sabine Pütter, Elena Vedmedenko, Robert Frömter, and •Hans Peter Oepen — Institut für Angewandte Physik, Universität Hamburg, Jungiusstr. 11, 20355 Hamburg

Soft magnetic materials like permalloy ($Ni_{80}Fe_{20}$) are widely used for magnetic nano- and micrometer size elements. The magnetic properties are controlled by the shape of the elements [1]. For rectangular elements with an aspect-ratio of 1:2 two configurations avoiding magnetic poles are found: the Landau and the diamond pattern.

We have studied the micromagnetic structure of $1\,\mu\mathrm{m} \times 2\,\mu\mathrm{m} \times 23\,\mathrm{nm}$ elements utilizing a SEM with spin-polarization analysis (SEMPA). An array of well separated elements contains Landau and diamond patterns with equal frequency, as expected from micromagnetic calculations [2]. The histogram of measured magnetization orientations reveals a splitting of the long axis magnetization for Landau structures, while the diamond shows four predominant directions. Analyzing the Landau structure obtained by micromagnetic simulations (OOMMF) reveals similar splitting. In chains of particles with the long edges separated by a gap smaller than particle size magnetostatic coupling occurs and solely Landau patterns are found. The splitting angle increases. A cross-tie wall like domain structure is created across the particles.

[1] A. Hubert and R. Schäfer, Magnetic Domains, (Springer, 1998).
[2] W. Rave and A. Hubert, IEEE Trans. Magn. **36**, 3886 (2000). R. Hertel, Zeitschrift für Metallkunde. **93**, 957 (2002).

MA 19.6 Wed 11:30 HSZ 403

Magnetic friction and "turbulence" at ferromagnetic surfaces — •Martin Magiera[1], Lothar Brendel[1], Dietrich E. Wolf[1], and Ulrich Nowak[2] — [1]Department of Physics, University of Duisburg-Essen, D-47058 Duisburg, Germany — [2]Department of Physics, University of Konstanz, D-78457 Konstanz, Germany

We theoretically study the magnetic contribution to friction force by simulating a ferromagnetic Heisenberg system scanned by a magnetic tip represented by a dipole field. The spin dynamics is given by the Landau-Lifshitz-Gilbert equation including a stochastic term describing thermal fluctuations. Friction force is calculated from energy dissipation terms, where thermal and magnetic energy flow contributions have to be distinguished.

For small velocities the friction force depends linearly on the scanning velocity, as well as on the phenomenological damping constant. This so-called laminar regime is in perfect agreement with our findings from a macrospin-model. Above a certain velocity vortices may occur, which propagate in the system – which is now called turbulent. Here the friction force measured is no more viscous, and its correlation with the occurence and propatation of vortices is studied.

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MA 19.7 Wed 11:45 HSZ 403

Propagation of spin waves through domain walls in Permalloy thin-film wires: scattering and interference — •Ming Yan, Sebastian Gliga, Riccardo Hertel, and Claus Schneider — Research Centre Jülich, Institute of Solid State Research, 52425 Jülich

The influence of domain walls on propagating spin waves is of great interest to both fundamental physics and potential applications in novel logic devices [1]. Using a finite-element micromagnetic code, we simulate the propagation of monochromatic spin waves through transverse and vortex walls formed in Permalloy thin-film wires. At lower frequencies, the planar waves propagate through the domain walls without being noticeably scattered. A phase shift, however, is induced by the domain walls as reported in Ref. [1]. At higher frequencies, periodic interference patterns are generated after the planar waves have been scattered by the domain walls. These patterns can be understood in terms of self-interference of the scattered waves or, alternatively, as the superposition of the original planar wave and the allowed transmission modes for the magnetic strip acting as a waveguide. These modes are quantized along the width direction of the wire and can be either symmetric or anti-symmetric with respect to the central wire axis. Similar interference effects of spin waves have also been observed recently in transversely magnetized wires without domain walls [2].

References [1] R. Hertel, W. Wulfhekel, and J. Kirschner, Phys. Rev. Lett. 93, 257202 (2004) [2] V. E. Demidov, S. O. Demokritov, K. Rott, P. Krzysteczko, and G. Reiss, Phys. Rev. B 77, 064406 (2008)

MA 19.8 Wed 12:00 HSZ 403

Stimulated vortex-antivortex pair creation in ferromagnetic thin film elements — •Sebastian Gliga, Riccardo Hertel, and Claus M. Schneider — Institut für Festkörperforschung (IFF-9), Forschungszentrum Jülich, Jülich, Germany

Charged pair production from the vacuum is a ubiquitous phenomenon in quantum mechanics, and can be triggered by high-intensity focused laser pulses. Using micromagnetic simulations, we demonstrate that the production of vortex-antivortex pairs can equally be stimulated by applying a strong local field in the direction opposite to the magnetization, even in samples too small to permanently sustain a vortex-antivortex structure. The dynamics of such pairs has recently attracted increased attention: they play a crucial role in the vortex core reversal process [1] and it has also been found that they could annihilate in zero field [2], interact with each other altering their dynamic behavior [3] or rotate under the influence of a DC spin-polarized current [4]. As an example of pair creation, we show that a short 1.2 Tesla field pulse over a small region (20 nm^3) in a sub-micron sized Permalloy disk of 20 nm thickness leads to the temporary creation of a vortex-antivortex pair. This pair production is consistent with the local increase of the energy density due to the applied field. These energy densities are compared to the ones found during the vortex core switch process.

[1] R. Hertel et al., Phys. Rev. Lett. 98, 117201 (2007); [2] R. Hertel and C. M. Schneider, Phys. Rev. Lett. 97, 177202 (2006); [3] K. Kuepper et al., Phys. Rev. Lett. 99, 167202 (2007); [4] G. Finocchio et al., Phys. Rev. B 78, 174408 (2008)

MA 19.9 Wed 12:15 HSZ 403

Annihilation of 360°-domain-walls by high-frequency magnetic field pulses. — •Felix Kurth, Rudolf Schäfer, Jeffrey McCord, and Ludwig Schultz — Leibniz Institute for Solid State and Materials Research IFW Dresden, P.O. Box 270116, 01171 Dresden, Germany

360°-domain-walls are metastable blocked domain walls in thin magnetic films. Such walls are only removable in external fields much higher than needed for regular 180° Neel-wall movement. In order to eliminate the walls magnetic fields up to 10 times the regular coercivity field of the system and well above the apparent saturation fields are necessary. The process of wall annihilation was studied by Kerr microscopy in the longitudinal mode in patterned Permalloy/Ta/CoFe (50 nm/4 nm/5 nm) thin magnetic double-layers. We were able to remove the 360° -walls by high-frequency magnetic field pulses significantly lower in amplitude than the quasi-static fields necessary for wall annihilation. The demonstrated route of 360°-wall annihilation by hf-pulses introduces a new path to homogenize the magnetization in patterned magnetic thin films for sensor applications. Possible annihilation mechanisms will be discussed.

MA 19.10 Wed 12:30 HSZ 403

Chiral symmetry breaking in magnetic vortices due to sample roughness. — •Arne Vansteenkiste[1], Bartel Van Waeyenberge[2], Markus Weigand[2], Michael Curcic[2], Hermann Stoll[2], and Gisela Schutz[2] — [1]Ghent University, Gent, Belgium — [2]Max Planck Institute for Metals Research, Stuttgart, Germany

An asymmetry between magnetic vortices with core polarizations up and down has been experimentally observed for square and disk-shaped nanostructures. E.g., different vortex core switching threshold excitations were measured, which was unexpected since the two core polarizations in these structures should behave perfectly symmetric. It was suggested that, e.g., surface roughness might cause the symmetry breaking, but it remained unclear if a small roughness could cause such a large asymmetry.

We have investigated the symmetry breaking with a new 3D finite-element micromagnetic package, which is specifically designed to handle non-perfect thin-film structures. The package uses a modified fast multipole method to calculate magnetostatic fields efficiently, without breaking the intrinsic symmetry of the sample, and employs a dynamically adaptive mesh to speed-up the calculations.

Our simulations confirm that a small roughness can indeed cause a large symmetry breaking between the two vortex core polarizations. The asymmetry can be explained by the lack of mirror-symmetry of the rough thin-film structures. The local character of the roughness causes a strong coupling with the vortex core and consequently a large asymmetry.