MA 9: Micromagnetism/Computational Magnetics

Time: Monday 16:45–18:15 Location: H 1012

MA 9.1 Mon 16:45 H 1012

Magnetic Contribution to Friction — •Martin P. Magiera and Dietrich E. Wolf — Department of Physics, University of Duisburg-Essen, 47048 Duisburg, Germany

We theoretically study the magnetic contribution to friction force by simulating an atomic anisotropic ferromagnetic Heisenberg system moving relative to a nanometer scaled extra spin. Interaction in between them is described by dipole interaction (cut off to avoid finite size effects). For integration of the dynamic system we use the Landau Lifshitz Gilbert equation. Langevin dynamics provide an insight into thermal effects. Friction force is calculated by derivation of energy dissipation terms and distinction of thermal and magnetic energy flow contributions.

We find a linear velocity dependence of the friction force, analogous to mechanical models like the Tomlinson model. Its slope is proportional to the phenomenological damping parameter in the Landau Lifshitz Gilbert equation, in agreement with the fluctuation dissipation theorem. Finally we find a nonzero friction and slope in the paramagnetic phase, as well as a rather complex friction force vs. velocity behavior at higher velocities. Hence we interpret the dissipation mechanism as an excitation of spin waves with a finite spectrum.

MA 9.2 Mon 17:00 H 1012

Hybrid FEM-BEM method for Oersted field calculation — •Riccardo Hertel — Forschungszentrum Jülich, Institut für Festkörperforschung IFF-9, D-52425 Jülich

Various exciting aspects of the current-induced magnetization dynamics in nanostructures due to spin-transfer torque effects have attracted overwhelming interest recently, particularly in the past five years. The interest in this new kind of spin dynamics is in fact so great, that the classical interaction between the magnetization and electric currents due to Maxwell has almost been overlooked. In the case of nanomagnets excited by a spin-polarized current in a pillar geometry, however, the magnetic field created by the current (i.e., the Oersted field) often provides a non-negligible contribution to the magnetization dynamics. Hence, micromagnetic simulations on current-driven dynamics require methods for accurate calculation of the Oersted field. In principle, the whole current-carrying structure (including, e.g., the contacting leads and the magnetic pillar) needs to be considered for reliable Oersted field calculation, i.e., a region which is much larger than the nanomagnet itself. In this talk I will present a hybrid finite-element / boundary method for the calculation of current density distributions and the resulting Oersted field in general geometries. This method can be easily implemented in finite-element micromagnetic simulation techniques because the involved matrix elements are the same as those used for the magnetostatic (dipolar) interaction.

MA 9.3 Mon 17:15 H 1012

Resonant and non-resonant current-induced vortex core switching — •Sebastian Gliga, Yaowen Liu, Riccardo Hertel, and Claus M. Schneider — Institut für Festkörperforschung (IFF-9), Forschungszentrum Jülich GmbH, D-52425 Jülich, Germany

It has recently been demonstrated that the core of magnetic vortices in thin-film elements can be switched by in-plane electrical currents [1,2]. Presently, two distinct routes are known by which electric currents flowing in the sample plane can switch a magnetic vortex core. In the resonant switching, the gyrotropic mode of the vortex is excited by applying a sinusoidal electric current tuned at the corresponding frequency [1], typically below one GHz for mesoscopic thin film elements. In contrast, the non-resonant switching consists in applying a single current pulse [2] to trigger the core reversal within a few hundreds of picoseconds. Using fully three-dimensional micromagnetic simulations based on the finite-element method, we have compared the electrical core switching processes for both routes. We have found that the reversal is mediated by the temporary creation of a vortex-antivortex pair in both cases. Moreover, the core switching occurs as soon as the total and the exchange energies reach critical threshold values in the sample. These thresholds are the same for the resonant and the non-resonant cases, and do not depend on the amplitude of the applied current. The time needed to switch the vortex core thus depends on the rate at which the sample energy increases due to the applied current.

[1] K. Yamada et al., Nat. Mat. **6**, 270 (2007)
[2] Y. Liu et al., Appl. Phys. Lett. **91**, 112501 (2007)

MA 9.4 Mon 17:30 H 1012

Influence of the Oersted field on the current-induced dynamics of nanodisks — •Attila Kakay, Riccardo Hertel, Ronald Lehndorff, Daniel Bürgler, and Claus Michael Schneider — Institut für Festkörperforschung IFF-9 "Elektronische Eigenschaften", Forschungszentrum Jülich, GmbH, D-52425 Jülich, Deutschland

Stationary oscillations of the magnetization in nanopillars with characteristic frequencies in the GHz range can be induced by a spin-polarized dc current. The frequency of these oscillators is tunable by changing the current value or other external parameters. Experimental research shows that in some cases the frequency increases with increasing current density, an effect known as blue-shift. This blue-shift effect has been studied both experimentally and numerically. In the commonly used macrospin model, where the exchange energy is neglected, this blue-shift is assigned to out-of-plane precessional modes of the magnetization. Our full-scale micromagnetic simulation provides a different explanation for the blue-shift, showing that it originates from the Oersted field. The mode profiles of the characteristic magnetization dynamics around 8 GHz are extracted using spatial Fourier filtering. In the presence of the Oersted field the mode profile is changing with increasing current in such way, that the distance between the oscillating regions decreases, which leads to the increase of the oscillating frequency, thereby explaining the observed blue-shift. Good quantitaive agreement is obtained between simulations and experiment regarding both the main frequency and its shift.

MA 9.5 Mon 17:45 H 1012

three-dimensional magnetic normal modes in mesoscopic permalloy prisms — •Ming Yan, Riccardo Hertel, and Claus Michael Schneider — Institut für Festkörperforschung, IFF-9, Forschungszentrum Jülich, D-52425 Jülich

Three-dimensional (3D) magnetic normal modes in Permalloy prisms (aspect ratio 4:2:1, thickness 60-80 nm) with 3D Landau structure [1] are studied using micromagnetic finite-element simulations. Magnetic normal modes are extracted with Fourier analysis from the dynamical response of the magnetization to a weak sub-nanosecond field pulse. Among the rich excitation spectra in the range of several GHz, three well-defined types of modes are resolved: the oscillations of the asymmetric Bloch wall, of the corners, and of the 90° domain walls [2]. The modes connected with the asymmetric Bloch wall can be interpreted as the oscillations of a distorted, stretched vortex core. Instead of just one gyrotropic vortex core mode as it is known from 2D systems, multiple core modes are observed in our 3D samples. The other two types of modes, although similar to those known from 2D systems, show different characteristics consistent with the 3D character of the sample and the asymmetry of the magnetic ground state. These simulations provide precise predictions on the excitation spectra in 3D prisms and extend the knowledge of dynamic modes in confined magnetic structures from two dimensions to three. [1] R. Hertel, O. Fruchart, S. Cherifi, P.-O. Jubert, S. Heun, A. Locatelli, and J. Kirschner, Phys. Rev. B 72, 214409 (2005). [2] M. Yan, R. Hertel, C. M. Schneider, Phys. Rev. B 76, 094407 (2007).

MA 9.6 Mon 18:00 H 1012

Computer experiments on standing spin wave resonances using Landau-Lifshitz-Gilbert dynamics — •Robert Wieser, Elena Y. Vedmedenko, and Roland Wiesendanger — Institute of Applied Physics, University of Hamburg, Jungiusstrasse 11, D-20355 Hamburg

A new method to explore standing spin wave patterns based on the solution of the Landau-Lifshitz-Gilbert equation in two-dimensional nanostructures will be presented. We calculate numerically the power spectrum P of magnetic moments in an oscillating field. The simulations are directly comparable with classical ferromagnetic resonance experiments, where the imaginary part of the susceptibility $\chi'' \propto P$ is observed. The advantage of this method is the direct information about the position and phase of the spin wave resonance as function of frequency or external magnetic field.

In the second part of the talk, the temperature dependence of the resonance spectrum of Fe/Ag(111) will be discussed. The temperature causes a shift in the $T = 0$ resonance peaks as well as additional spin wave patterns.

ACKNOWLEDGMENTS: This work has been supported by the Deutsche Forschungsgemeinschaft (SFB 668).