MA 37: Spin Torque and Spin Excitations I

Time: Thursday 9:30–12:15 Location: HSZ 401

MA 37.1 Thu 9:30 HSZ 401

Goldstone modes observed in a single-k weak chiral magnet — •Max Kugler[1], Georg Brandl[1], Robert Georgii[1], Peter Böni[2], Christian Pfleiderer[2], Achim Rosch[3], Markus Garst[3], and Johannes Waizner[3] — [1]Heinz Maier-Leibnitz Zentrum (MLZ), TU München — [2]Physik Department E21, TU München — [3]Institute for Theoretical Physics, University of Cologne

The dispersion of the helimagnon modes in the weak chiral helimagnet MnSi has been measured in the momentum directions **q** parallel and perpendicular to the helix wave vector **k** using triple-axis neutron spectroscopy (TAS). In contrast to earlier measurements by Janoschek *et al.* [1], where the measurements were performed in a multi-domain state leading to the appearance of numerous modes, we applied a small magnetic field of 100 mT to enforce a single domain state thus reducing the number of modes drastically. Therefore, we succeeded to clearly identify the various magnetic modes and measure their dispersion. By inclusion of an energy gap all the data can be well reproduced by the theory on helimagnons by Belitz *et al.* [2]. However, the energy gap can neither be explained by dipolar interactions nor by the applied field because of the Goldstone theorem. For $\mathbf{q} \perp \mathbf{k}$, a multiple band structure develops in which we succeeded to resolve the first six bands. Furthermore, we investigated the renormalization of the helimagnons for both **q**-directions and achieved an excellent agreement with our magnetisation data and previous measurements in the field-induced ferromagnetic state.

[1] PRB **83**, 214436 (2010) [2] PRB **73**, 054431 (2006)

MA 37.2 Thu 9:45 HSZ 401

Tuning Spin Transfer Torques in Chiral Magnets — •Christoph Schnarr, Robert Ritz, Andreas Bauer, Christian Franz, and Christian Pfleiderer — Technische Universität München, Physik-Department E21, D-85748 Garching, Germany

Small angle neutron scattering and Hall effect measurements recently revealed sizeable effects of spin transfer torques in the skyrmion lattice phase of MnSi [1,2]. The associated critical current densities of $\sim 10^6 \mathrm{Am}^{-2}$ are exceptionally small and about 5 orders of magnitude smaller than the spin transfer torques observed in conventional systems. The low critical current density is due to a very efficient gyromagnetic coupling due to the non-trivial topology of the skyrmion lattice, as well as combination of stiffness of the skyrmion lattice and collective pinning. We report spin transfer torque experiments, based on the Hall effect in chiral magnets for various tuning parameters, where the topological Hall effect increases by up to a factor of ten suggesting a large variation of the coupling of the electric currents to the magnetic structure. The dependence of j_c on the tuning parameters will be discussed in view of the increased topological Hall effect as well as the increased pinning by disorder.

[1] F. Jonietz et al., Science **330**, 1648-1651 (2010)
[2] T. Schulz et al., Nat Phys **8**, 4, 301-304 (2012)

MA 37.3 Thu 10:00 HSZ 401

Topologically Protected Magnetic Helix for All-Spin-Based Applications — •Elena Vedmedenko and David Altwein — Universität Hamburg, Deutschland

The recent years have witnessed an emergence of the field of all-spin-based devices without any flow of charge. An ultimate goal of this scientific direction is the realization of full spectrum of spin-based networks like in modern electronics. The concepts of energy storing elements, indispensable for those networks, are so far lacking. Analyzing analytically the size dependent properties of magnetic chains that are coupled via either exchange or long-range dipolar or Ruderman-Kittel-Kasuya-Yosida interactions, we discover a particularly simple law: magnetic configurations corresponding to helices with integer number of twists, that are commensurate with the chain's length, are energetically stable. With increasing number of twists the energy of the helix increases but, once achieved, remains stable at small temperatures. The higher energy levels can be reached by rotating one of the chain ends like the winding up of spring driven clocks. This finding, supported by simulations and an experimentally benchmarked model, shows that boundaries can topologically stabilize structures that are not stable otherwise. On that basis an energy storing element that uses spin at every stage of its operation is proposed [1].

[1] E. Y. Vedmedenko, D. Altwein, Phys. Rev. Lett., accepted (2013).

MA 37.4 Thu 10:15 HSZ 401

Spin dynamics and magnon lifetime close to the percolation in two dimensional diluted magnetic systems — •Akash Chakraborty[1], Paul Wenk[1], John Schliemann[1], and Georges Bouzerar[2] — [1]Institut I - Theoretische Physik, Universität Regensburg, 93040 Regensburg, Germany — [2]Institut Lumiere Matiere, Universite Lyon 1-CNRS, 69622 Villeurbanne Cedex, France

Spin-wave excitations in disordered magnetic systems have been widely studied for several decades now. However, a careful search reveals a longstanding controversy on one important aspect, which is the wave-vector dependence of the spin-wave intrinsic linewidth. Different theories have predicted this dependence to be as varied as q^3 to q^7, but no general agreement has prevailed till now. We present here a detailed analysis of the low-temperature spin-wave excitations in two-dimensional diluted ferromagnetic systems and show that in the long wavelength limit the linewidth is in fact proportional to q^4. This is in good agreement with some previous theoretical studies which predicted a q^{d+2}dependence (d is the dimensionality). One of the primary difficulties in extracting the correct wave-vector dependence is the fact that this q^4 behavior holds only for very small q-values, in a restricted region of the Brillouin zone. This possibly explains the failure to observe this behavior experimentally, as it is considerably difficult to probe such small wave-vectors. In addition, we show that evaluating the linewidth from the moments associated with the spectral density leads to an incorrect linear dependence in q.

MA 37.5 Thu 10:30 HSZ 401

Self-consistent determination of the key spin transfer torque parameters from spin wave Doppler experiments — •Helmut Körner, Jean-Yves Chauleau, Hans Bauer, Johannes Stigloher, Georg Woltersdorf, and Christian Back — Department of Physics, Universität Regensburg, D-93040 Regensburg, Germany

Action of spin-polarized electric currents on magnetic textures is now well established both from experimental and theoretical viewpoints [1]. These effects are known as spin-transfer torques (STT). In the case of continuous magnetic distributions, current-induced domain wall (DW) dynamics is a recurrent system of investigation. However, DWs are fairly complicated magnetic structures whose dynamics is consequence of a subtle combination of damping, spin-drift velocity and non-adiabatic parameter. An alternative to domain walls dynamics has been reported by Vlaminck and Bailleul. The current-induced shift of spinwave resonances (spinwave Doppler shift) has been experimentally evidenced using an inductive approach [2].

In this study, we experimentally determine the key spin transfer torque parameters in a fully self-consistent approach by optically accessing current-induced spinwave dynamics in Permalloy stripes using time-resolved scanning Kerr microscopy (TRMOKE). Our technique allows precise access to spinwave characteristics and their current-induced changes, especially the change in decay length which carries the information about the non-adiabaticity.

[1] D.C. Ralph and M.D. Stiles, JMMM 321, 2508 (2009) [2] V. Vlaminck and M. Bailleul, Science 322, 410 (2008)

15 min. break

MA 37.6 Thu 11:00 HSZ 401

Influence of conduction electrons on spin dynamics — •Andreas Donges, Denise Hinzke, and Ulrich Nowak — University Konstanz, 78457 Konstanz, Germany

Current-induced domain wall (DW) motion due to the exchange interaction of s- and d-electron spins promises novel applications in data storage technologies [1]. However, when it comes to narrow DWs the spin-torque-description by Zhang and Li [2], used to describe this interaction, is not sufficient anymore and one has to take into account additional effects, such as spin-diffusion and spin-current-precession.

We numerically investigate current-driven DW motion in narrow walls using a 1-dimensional model, where localized d-electron spins are described by the Landau-Lifshitz-Gilbert-equation, whereas the equation of motion for the itinerant s-electrons has been derived from the spinor-Boltzmann-equation. Both equations are coupled via a local sd-exchange Hamiltonian and we neglect finite temperature effects. The DW velocity is studied in dependence of the wall width. We find a monotonic increase of the velocity with decreasing wall width, caused by non-equilibrium-spin-diffusion. Some systems show an additional rise in the DW velocity, when the wall width is near the spin-diffusion-length, that we link to the missing alignment of s- and d-electron-profiles.

[1] S. Parkin, et al., Science, 320, 5873 (2008)
[2] S. Zhang and Z. Li, Phys.Rev.Lett., 93, 12 (2004)

MA 37.7 Thu 11:15 HSZ 401

Spin-orbit torques in magnetic nanostructures with structural inversion asymmetry — •Roberto Lo Conte[1,3], Ales Hrabec[2], Andrei Mihai[2], Tomek Schulz[1], Thomas Moore[2], and Mathias Kläui[1,3] — [1]Institute of Physics, Johannes Gutenberg University, Staudingerweg 7, 55128 Mainz, Germany — [2]School of Physics and Astronomy, University of Leeds, LS2 9JT, U.K. — [3]Graduate School Material Science in Mainz (MAINZ), Staudingerweg 9, 55128 Mainz, Germany

Intense investigations are carried out on novel magnetic materials systems with perpendicular magnetic anisotropy (PMA) and structure inversion asymmetry (SIA). So called spin-orbit torques (SOTs) have been observed in PMA nanostructures with SIA when an electric current is injected, leading to ultra-fast current-induced domain wall motion (CIDWM) and current-induced magnetization switching [1,2]. We investigate CIDWM in PMA-nanowires made of Ta/CoFeB/MgO and Pt/CoFeB/MgO by Kerr Microscopy. By measuring the effect of an in-plane external magnetic field on the DWM, we determine the acting torques. At sufficiently large longitudinal fields we observed a strong change in the DW velocity, of different sign for the two types of DWs. This demonstrates that Néel-type DWs maximize the acting torques and that the chirality of the DWs is fixed by the Dzyaloshinskii-Moriya interaction (DMI) generated at the interfaces [3,4]. We determine the strength of the DMI-effective field and we find that in combination with the spin Hall effect in Ta and Pt, this leads to efficient wall motion in opposite directions for Ta and Pt underlayers.

MA 37.8 Thu 11:30 HSZ 401

Non-local spin transfer torque and its effect on domain wall motion — •Martin Stier and Michael Thorwart — I Institut für Theoretische Physik, Universität Hamburg, Jungiusstraße 9, 20355 Hamburg, Germany

Current induced domain wall (DW) motion is well described by the Landau-Lifshitz-Gilbert equation which includes spin transfer torques (STT). Standard procedures lead to essentially two parts of the STT (adiabatic, non-adiabatic) which are considered to be spatially constant even in the vicinity of the DW. We present a basically exact method to solve the continuity equation which results in a non-local STT. This STT now depends sensitively on several model parameters, most prominently on the DW width, but also on the exchange coupling and the non-adiabaticity parameter. Additionally we find a quite natural reflection of the relaxation length in the STT. While for broad DWs the standard expressions of the STT are recovered, they differ completely for steep DWs. Finally, we show how the non-local STT affects the DW velocity including the impossibility to move very steep DWs.

MA 37.9 Thu 11:45 HSZ 401

Micromagnetic simulation of a spin-torque oscillator driven by pure spin currents — •Henning Ulrichs, Vladislav E. Demidov, and Sergej O. Demokritov — Institut für angewandte Physik, WWU Münster, Corrensstraße 2-4, 48149 Münster

In this talk a micromagnetic simulation of a novel kind of spin torque nano-oscillator compromising a patterned Pt / NiFe double layer is presented. The operational principle of this oscillator relies on the spin-Hall effect in the Pt. In contrast to conventional spin-torque oscillators, the spin-torque is conveyed by pure spin currents, flowing from the Pt into the NiFe. The numerical results support the experimental claim that the dominant auto-oscillation mode is the spin-wave bullet mode. Moreover, a recently experimentally observed secondary mode is also found in the simulation. Spatial features of the bullet mode, which are in experiments obscured due to optical limitations, are investigated. It is shown that the diameter of the spin-wave bullet is about 80 nm. The physical nature of the secondary mode is elucidated.

MA 37.10 Thu 12:00 HSZ 401

Spin torque switching of an in-plane magnetized system in a thermally activated region — Tomohiro Taniguchi[1], Yasuhiro Utsumi[2], •Michael Marthaler[3], Dmitri Golubev[3], and Hiroshi Imamura[1] — [1]Spintronics Research Center, AIST, Tsukuba — [2]Faculty of Engineering, Mie University, Tsu — [3]Institut für Theoretische Festkörperphysik, KIT, Karlsruhe

The current dependence of the exponent of the spin torque switching rate of an in-plane magnetized system was investigated by solving the Fokker-Planck equation with low temperature and small damping and current approximations. We derived the analytical expressions of the critical currents, I_c and I_c^*. At I_c, the initial state parallel to the easy axis becomes unstable, while at I_c^* ($\simeq 1.27 I_c$) the switching occurs without the thermal fluctuation. The current dependence of the exponent of the switching rate is well described by $(1 - I/I_c^*)^b$, where the value of the exponent b is approximately unity for $I < I_c$, while b rapidly increases up to 2.2 with increasing current for $I_c < I < I_c^*$. The linear dependence for $I < I_c$ agrees with the other works, while the nonlinear dependence for $I_c < I < I_c^*$ was newly found by the present work. The nonlinear dependence is important for analysis of the experimental results, because most experiments are performed in the current region of $I_c < I < I_c^*$.