MA 39: Focus Session: Unconventional Spin Structures (jointly with DS)

Organizer: J. Fassbender (HZDR)

Time: Thursday 9:30–12:45 Location: BEY 118

Topical Talk MA 39.1 Thu 9:30 BEY 118

Topological Effects in Nanomagnetism - From Perpendicular Recording to Monopoles — •Hans-Benjamin Braun — University College Dublin

Similar to knots in a rope, the magnetization in a material can form particularly robust configurations. Such topologically stable structures include domain walls, vortices and skyrmions which are not just attractive candidates for future data storage applications but are also of fundamental importance to current memory technology. For example, the creation of soliton pairs of opposite chirality delimits the thermal stability of bits in current high anisotropy perpendicular recording media. After an introduction into various types of topological defects and their implications for current data storage it will be discussed how vortices can be robustly implemented in a system of nanoislands, a system that is in principle scaleable to the smallest length scales. It will then be shown how magnetic monopoles emerge as topological defects in densely packed arrays of nanoislands, a system also known as artificial spin ice. In contrast to conventional thin films, where magnetization reversal occurs via nucleation and extensive domain growth, magnetization reversal in 2D artificial spin ice is restricted to an avalanche-type formation of 1D strings. These objects can be viewed as classical versions of Dirac strings that feed magnetic flux into the emergent magnetic monopoles. It is demonstrated how the motion of these magnetic charges can be individually controlled experimentally and used to perform simple logic operations.

Topical Talk MA 39.2 Thu 10:00 BEY 118

Topology and Origin of Effective Spin Meron Pairs in Ferromagnetic Multilayer Elements — •Sebastian Wintz — Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany

Topological spin textures, such as vortices or skyrmions, are attracting significant attention because of their intriguing fundamental properties as well as their promising applicability in memory devices or spin torque oscillators. A particular topological texture that was theoretically predicted is the two-dimensional hedgehog state, also known as a 'Spin Meron'. It had been unclear, however, whether this kind of highly divergent magnetization structure can exist in real continuum systems. Only recently, evidence for the occurrence of meron-like states was reported for trilayer elements consisting of two ferromagnetic layers and a non-ferromagnetic interlayer [1]. On this background we now present a direct proof for the existence of meron-like states in trilayer elements via direct magnetic imaging. We also show that in the presence of biquadratic interlayer exchange coupling, such meron-like pair states may even represent the magnetic ground state of the system. Interestingly, the highly divergent magnetization distribution induces an additional, three-dimensional torus vortex that in-turn causes a symmetry break for the allowed topological pair configurations. [1] C. Phatak et al., Phys. Rev. Lett. 108, 067205 (2012). [2] S. Wintz et al., Phys. Rev. Lett. 110, 177201 (2013).

Topical Talk MA 39.3 Thu 10:30 BEY 118

Symmetry breaking in the formation of magnetic vortex states in a permalloy nanodisk — •Peter Fischer[1], Mi-Young Im[1], Keisuke Yamada[2], Tomonori Sato[3], Shinya Kasai[4], Yoshinobu Nakatani[3], and Teruo Ono[2] — [1]CXRO, LBNL, Berkeley CA USA — [2]Inst. f.Chem. Res., Kyoto University Japan — [3]U of Electro-Comm., Chofu, Japan — [4]Spintronics Group, Magn. Mat Center, NIMS, Tsukuba, Japan

Mesoscale phenomena will transform nanomagnetism research to the next level [1], as they add complexity and functionality, which are essential to meet future challenges of spin driven devices.

A priori, one would assume that the formation of magnetic vortex states should exhibit a perfect symmetry, because the magnetic vortex has four degenerate states. We report on the direct observation of an asymmetric phenomenon in the formation process of vortex states in a permalloy nanodisk by magnetic full field transmission soft x-ray microscopy [2]. Micromagnetic simulations confirm that an intrinsic Dzyaloshinskii*Moriya interaction is decisive for the asymmetric formation of vortex states.

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[1] R. Service, Science 335 1167 (2012) [2] M.-Y. Im, P. Fischer, Y. Keisuke, T. Sato, S. Kasai, Y. Nakatani, T. Ono, Nature Communications 3 983 (2012)

15 min. break

Topical Talk MA 39.4 Thu 11:15 BEY 118

Commensurability and chaos in magnetic vortex oscillations — •Joo-Von Kim[1], Sébastien Petit-Watelot[1], Antonio Ruotolo[2,3], Rubén Otxoa[1], Karim Bouzehouane[2], Julie Grollier[2], Arne Vansteenkiste[4], Ben Van de Wiele[5], Vincent Cros[2], and Thibaut Devolder[1] — [1]Institut d'Electronique Fondamentale, UMR CNRS 8622, Univ. Paris-Sud, 91405 Orsay, France — [2]Unité Mixte de Physique CNRS/Thales and Univ. Paris-Sud, 1 av. A. Fresnel, 91767 Palaiseau, France — [3]Department of Physics and Materials Science, City University of Hong Kong, Kowloon, Hong Kong — [4]Department of Solid State Sciences, Ghent University, Krijgslaan 281-S1, B-9000 Ghent, Belgium — [5]Department of Electrical Energy, Systems and Automation, Ghent University, Sint-Pietersnieuwstraat 41, B-9000 Ghent, Belgium

In spin-torque driven vortex oscillations in small nanocontacts, periodic reversal of the vortex core appear above a critical current and results in a self-modulation phenomenon involving gyration and relaxation oscillations. By tuning the ratio between the gyration frequency and the rate of core reversal, we show that commensurate phase-locked and incommensurate chaotic states are possible, resulting in Devil's staircases with driving currents. This represents a novel dynamical regime for vortex dynamics in which the gyrotropic dynamics is self-modulated by the periodic core reversal.

Topical Talk MA 39.5 Thu 11:45 BEY 118

Dynamic ordering of vortex cores in interacting mesomagnets — •Valentyn Novosad — Materials Science Division, Argonne National Laboratory, Argonne, IL 60439, USA

Manipulation of the magnetization is a key problem in applied magnetism. In this talk a novel method of controlling the ground state using two interacting vortices as a model system will be presented. A spin vortex consists of an in-plane and out-of-plane (core) regions of magnetization. Control of an in-plane magnetization has been demonstrated previously, whereas manipulation of the vortex cores remain challenging. In our work this is achieved by driving the system from the linear regime of constant vortex gyrations to the non-linear regime of vortex-core reversals at a fixed excitation frequency of one of the coupled modes. Subsequently reducing the excitation field to the linear regime, stabilizes the system to a polarity combination whose resonant frequency is decoupled from the initialization frequency [2]. The transition of the state from one polarity combination to the other is clearly evident from the contrast in the microwave absorption amplitude obtained by gradually increasing the rf-field to higher magnitudes at the resonant frequency of one of the modes and subsequently decreasing it. The results of this work may benefit future advancement of dynamically controlled spintronic devices, such as magnonic crystals, spin-torque oscillators, and magnetic memories.

[1] S. Jain, et al., Applied Physics Letters, 102, 052401 (2013).
[2] S. Jain et al., Nature Comm., DOI: 10.1038/ncomms2331 (2012).

Topical Talk MA 39.6 Thu 12:15 BEY 118

Magnetic Vortex Core Reversal by Excitation of Spin Waves — •Hermann Stoll[1], Matthias Kammerer[1], Matthias Noske[1], Markus Sproll[1], Georg Dieterle[1], Ajay Gangwar[1,2], Markus Weigand[1], Manfred Fähnle[1], Georg Woltersdorf[2], Christian H. Back[2], and Gisela Schütz[1] — [1]MPI for Intelligent Systems, Stuttgart, Germany — [2]University of Regensburg, Germany

Essential progress in the understanding of nonlinear magnetic vortex dynamics was achieved when low-field vortex core reversal by (sub-GHz) excitation of the vortex gyromode was observed using time-resolved scanning transmission X-ray microscopy [1]. This switching scheme, based on the creation and subsequent annihilation of a vortex-antivortex pair [1,2], has been proved to be universal and independent of the type of excitation, e.g., pulsed magnetic fields or spin transfer torque (STT).

Magnetic vortex structures possess azimuthal spin wave modes showing eigenfrequencies in the multi-GHz range. We could demonstrate [3-5] by experiments and micromagnetic simulations that even much faster unidirectional vortex core reversal can be achieved by exciting these spin wave modes with (multi-GHz) rotating magnetic fields. In that way we have been able to switch vortex cores selectively within less than 100 ps.

[1] B. Van Waeyenberge et al., Nature 444, 462 (2006) [2] A. Vansteenkiste et al., Nature Physics 5, 332 (2009) [3] M. Kammerer et al., Nature Communications 2, 279 (2011) [4] M. Kammerer et al., PRB 86, 134426 (2012) [5] M. Kammerer et al., APL 102, 012404 (2013)