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Nonequilibrium Process of Magnetization Switching Influenced by Thermal Spin Fluctuations

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The magnetic domain configuration and its correlation to spin dynamics in micro- and nano-sized magnets has been actively studied during the last few years due to their possible applications in high-density magnetic storage devices [13]. In our study dynamic behavior of nonequilibrium magnetization configurations undergoing ultrafast magnetization reversal was studied with time-resolved scanning Kerr microscope and micromagnetic modeling. The magnetization switching dynamics enters a fully dynamic regime when the external field conditions are changed much faster than the magnetization in the elements is able to respond. We observe that the dynamic pathway develops a complexity not seen in quasi-static reversal, but still retains a high level of order with well-developed dynamic domain patterns formed in response to sub-nanosecond transitions of the external applied magnetic field. We discuss the systematic evolution of the spatiotemporal nature of the magnetization reversal of a small ferromagnetic platelet (*15 nm thick* $Ni_{80}Fe_{20}$ *square element with the size of* $10\times10\ \mu m^2$) to progressively faster switching fields. An increasing complexity in the spatial structure ofevolution is found to accompany the increasing switching speed, when a ferromagnetic element is driven by progressively faster reversing fields applied anti-parallel to the initial magnetization direction.This is in contrast to the case of quasi-ballistic switchinga nearly-uniform torque is applied to the entire magnetization and thermal nucleation is unimportant.As reversal rates approach the characteristic precession frequencies of spin fluctuations, the thermal energy can boost the magnetizationinto local *configurations which are completely different from those experienced during quasi-static reversal.* The sensitive dependence of the spatial pattern on switching speed can be understood in terms of a dynamic exchange interaction of thermally excited spins;the coherent modulation of the spins is strongly dependent on the rise time of switching pulses. Micromagnetic modeling agrees well with the experiment, and clearly illustrates the role of thermally excited spins in the formation of complex nonequilibrium domain structures. We also discuss the dynamics of vortex core switching by short magnetic field pulse in a submicron-scale Py disk. At zero magnetic field, the vortex state is formed with a single vortex core at the disk center. When an *in-plane* magnetic field pulse with an appropriate strength and duration is applied to the vortex state, an additional two vortices, i.e., a vortex and an anti-vortex, with an opposite polarity are created near the original vortex core. *Subsequently, the original vortex core annihilates with the antivortex core, and the final magnetic state contains a single core* with the reversed polarity. The dynamics of the vortex core switching can be understood in terms of the non-local torque exerted to spins in response to an externally applied magnetic field pulse. At finite temperatures, thermally excited spin fluctuations lead to an increasing complexity of nonequilibrium magnetization configurations.

REFERENCES

[1] B.C. Choi, J. Ho, G. Arnup, and M.R. Freeman, Phys. Rev. Lett. **95**, 237211 (2005).
[2] Q.F. Xiao, J. Rudge, B.C. Choi, Y.K. Hong, and G.W. Donohoe, Appl. Phys. Lett. **89**, 262507 (2006).
[3] Q.F. Xiao, J. Rudge, B.C. Choi, Y.K. Hong, and G.W. Donohoe, Phys. Rev. B **73**, 104425 (2006).

FC02

Observation of Coherence and of Partial Decoherence of Quantized Spin Waves in Nanoscaled Magnetic Ring Structures

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Spin dynamics in small confined structures is interesting with respect to fundamental understanding as well as in view of applications in, e.g., spin momentum transfer devices. The eigenmode spectra of small magnetic elements were discussed *extensively in the past. Yet the problem of (de-)coherence of spin waves* was not addressed so far, even though this is an essential requirement for the creation of an spin-wave eigenmode system.

We report on the quantization mechanisms and in particular on the transition of incoherent to coherent spin-wave excitations in permalloy rings with varying widths (from 200 to 400 nm) and diameters (from 1 to 3 μm). In addition we studied spin waves under the influence of domain walls, which can be nucleated in such ring structures when applying an external magnetic field.

The samples have been made starting from 15 nm thick permalloy films deposited in a UHV system using e-beam evaporation and using e-beam lithography for patterning. The magnetic excitations for both the vortex and the onion state of the rings were investigated by means of microfocus Brillouin light scattering spectroscopy with a spatial resolution of 250 nm. This technique allows for a local study of the magnetic excitations. For the vortex state in zero applied field the observed spin-wave frequencies are independent of the position along the ring, because of the rotational symmetry of the magnetization distribution. However for the onion state, whose magnetic configuration breaks the rotational symmetry, the spin-wave spectra are position dependent and several interesting effects were identified. First, in the pole regions, characterized by large stray fields, spin wave wells are created due to the inhomogeneous internal field, and consequently spatially coherent modes with constant frequencies as a function of position are detected in these areas. Second, in the regions in between, modes with constant frequencies are observed only for the smallest structures. These modes are quantized in radial and azimuthal directions as a consequence of spatial coherence and confinement in the rings structure. For rings of larger diameter a transition to a continuous frequency variation with position is observed. For the largest structures (ring diameter 3 μm) we conducted a model calculation and did micromagnetic simulations using the OOMMF code, both revealing excellent agreement with our experimental results.

Furthermore, investigation of the spin-wave spectra with high spatial resolution in regions of domain walls demonstrate, how spin dynamics is modified inside and around the domain walls due to the inhomogeneous magnetization and field distribution.

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