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Vortex-Antivortex Assisted Vortex Core Reversal in Magnetic Nano Dots

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Abstract – Vortex core dynamics have been investigated by time-resolved X-ray microscopy in magnetic nano dots. This high resolution imaging allowed for the observation of the dynamic vortex core deformation, providing the first direct support for the switching model based on creation and annihilation of a vortex-antivortex pair. The core switching was studied following short in-plane magnetic field pulses, showing easy switching when the vortex was coherently excited by leading and falling edges of the field pulse.

The reversal of the vortex core polarization via excitation of vortex gyration was discovered by time-resolved X-ray microscopy [1]. Derived from micromagnetic simulations, a model was suggested based on dynamic vortex-antivortex (VA) creation and annihilation [1]. Meanwhile this model is generally accepted for vortex core switching initiated by the excitation with in-plane Oersted fields (linear and circular fields, continuous and pulsed) and also by spin polarized currents. Now, other experimental techniques have also been used to study vortex core reversal [2-4]. However, in all of these experiments the vortex core polarization was only determined 'before' and 'after' the vortex core reversal and the evidence for the VA model is only indirect, by comparing the experimental parameters with micromagnetic simulations. No direct support for the VA model has been given so far.

We will present data supporting the VA model directly. According to this model, the vortex core switching process happens in distinct steps [1]: (i) Excitation induced gyration leads to a deformation of the out-of-plane core profile, i.e. a region with opposite magnetization is formed near the original vortex core.(ii) When the deformation reaches full out-of-plane magnetisation, a vortex-antivortex pair is nucleated. (iii) Finally the antivortex annihilates quickly with the original vortex, dissipating the excess energy in spin waves.

Time-resolved imaging of the out-of-plane vortex core magnetization has given direct evidence for the first step, the deformation of the vortex core [5]. A region with opposite magnetization becomes visible at sufficiently high excitation power when the vortex is gyrating fast and its velocity is approaching the critical velocity [2,6]. Here, the deformation reaches a maximum and can nucleate a VA pair, leading to core reversal. We evaluated the vortex core velocities under different excitations and could confirm the existence of a 'critical velocity' for the vortex [5].

Additionally, this time-resolved X-ray microscopy has enabled us to directly observe vortex core switching and localize it in space and time [7]. It was used the investigate vortex core switching by short magnetic field pulses. By 'coherent excitation', i.e., by taking advantage of the rising and the falling edge of a magnetic field pulse for acceleration, the field amplitude needed for vortex core reversal could be lowered significantly [7].

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