Magnetic Soft X-ray Imaging of Non-linear Vortex Core Dynamics

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The dynamics of magnetic vortices in micron sized ferromagnetic elements has recently attracted great scientific interest [1]. We report on the fabrication of nanopatterned magnetic samples for the direct real-space observation of non-linear vortex core dynamics in permalloy ($Fe_{20}Ni_{80}$) structures utilizing magnetic full field soft X-ray microscopy at the Advanced Light Source in Berkeley, which provides elemental sensitivity and magnetic contrast as well as a spatial resolution better than 25nm [2]. Permalloy squares and circles with lateral dimensions on the order of a micron and thickness from 70 to100 nm were fabricated for this study. The magnetic samples were aligned to 100nm thick gold waveguides, which were fabricated on silicon nitride membranes. An AC current sent through the waveguides creates an Oersted field at the sample and excites the resonant vortex core motion. Previous studies on such elements detecting the microwave absorption have found that at low amplitudes there is a single frequency that results in resonant gyrotropic motion, while at higher amplitudes two such resonance frequencies are detected [3], indicating the non-linearity of the gyrotropic vortex core dynamics.
Using the high resolution of soft X-ray microscopy the vortex core motion can be detected directly and compared to micromagnetic simulations.

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[1] K. Buchanan et al, Nature Physics, 1, 172, 2006
[2] S. Kasai, et al. Phys Rev Lett 101, 237203 (2008)
[3] P. Fischer, IEEE Transactions on Magnetics, 44(7) 1900 (2008)
[4] K. S. Buchanan, et al. *Phys. Rev. Lett.* **99**, 267201 (2007).

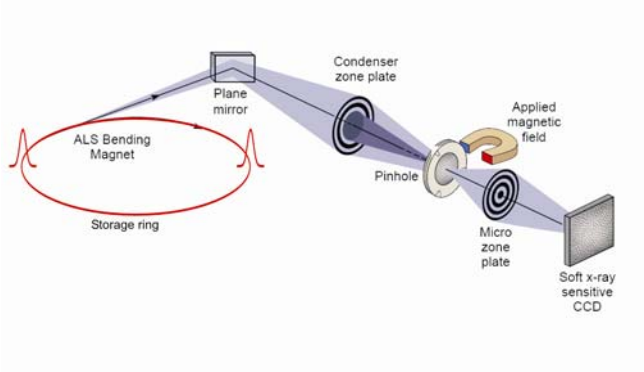

Figure 1. Schematic setup of the full-field soft X-ray microscopy beamline XM-1 at the Advanced Light Source in Berkeley, CA, USA.

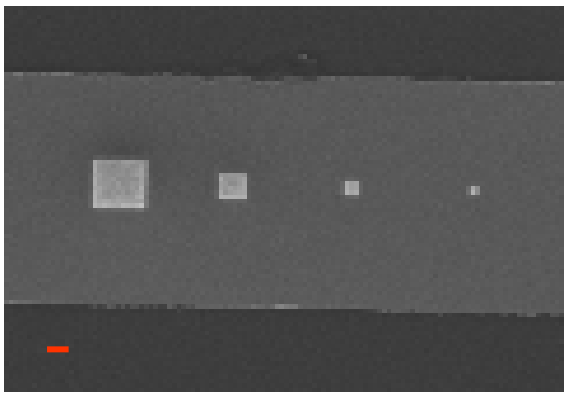

Figure 2. SEM image of permalloy square samples on a gold waveguide. Scale bar is 1um.

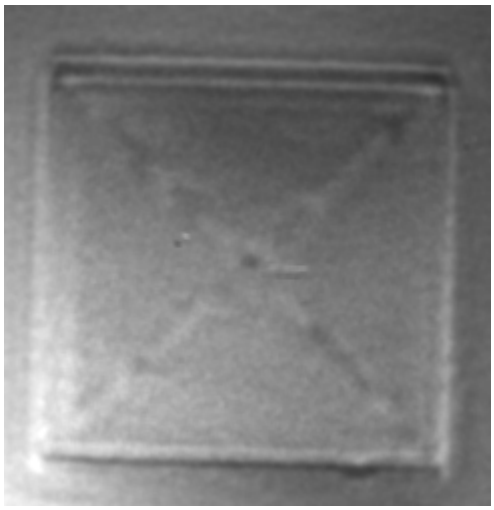

Figure 3. Image taken at XM-1 of the static magnetic configuration of a 2um by 2um square. The vortex core is visible as a black dot in the center of the structure.