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Dimensionality crossover in magnetic vortex dynamics[1]

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The ground state of a micron diameter ferromagnetic disk is often a single magnetic vortex, in which the gyrotropic mode of the vortex core is the lowest frequency excitation. In thin disks (thickness $L \ll$ diameter D), the vortex can be treated two-dimensionally (2D), and the gyrotropic frequency f_G is determined by L/D. We have observed a crossover from 2D to 3D dynamics as the thickness increases. Using time-resolved Kerr microscopy, we have investigated the gyrotropic mode in 1 μm diameter $Ni_{80}Fe_{20}$ disks as a function of L, which was varied from 20 nm to 200 nm. In thin disks ($L < 80$ nm), f_G is approximately proportional to L. For $L > 100$ nm, f_G increases less rapidly than predicted by the 2D model, and an additional gyrotropic mode appears at higher frequencies. We have explored the thickness dependences of both modes. In the ordinary gyrotropic mode, which is magnetostatic in character, the core oscillates uniformly through the thickness of the disk. The second gyrotropic mode is exchange-dominated, and the core oscillates with larger amplitude at the surfaces and a node in the equatorial plane of the disk. In the thickest disks, the exchange-dominated mode is the lowest in frequency.

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