Spin-Wave Excitation Spectra of Thick Magnetic Circular Dot in Vortex State

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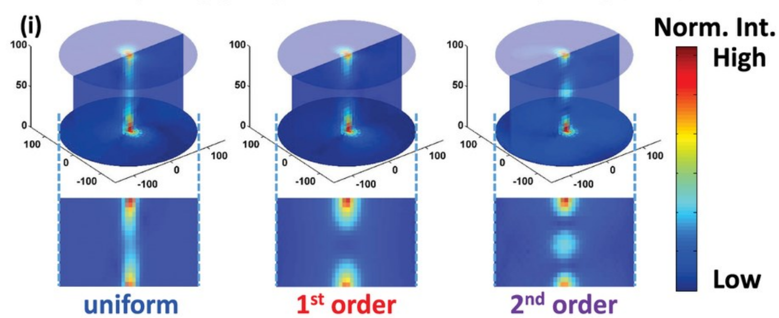
Magnetic vortex state excitations in relatively thick cylindrical $Ni_{80}Fe_{20}$ dots with radius of 150 nm and thicknesses varying from 20 to 100 nm were investigated experimentally and micromagnetically. Multiple spin excitation modes were detected using broadband ferromagnetic resonance spectroscopy in the frequency range 0.1-20 GHz in the absence of external magnetic field. The remarkable similarity between experimental and simulated microwave absorption spectra was found, allowing to consider micromagnetic simulations as a reliable tool to study in details intensity profiles of the observed modes and their evolution with time.

The spin-wave exitation spectra of thin (30 nm and below) circular ferromagnetic dot consists of uniform gyrotropic mode G_0 and doublets of azimuthal modes (±1 modes) with different radial indices, among which uniform along radial coordinate modes are the lowest and the most intensive. With further thickness increase the situation is getting more complicated. First, higher order gyrotropic modes G_1, G_2 (flexure oscillations of the vortex core string with $n = 1,2$ nodes along the dot thickness, see Fig.) become noticeable[1] and their relative intensities grow with thickness[2]. Second, at higher frequencies new modes having curled structure at surfaces and radial nodes at dot central plane appear[3]. Such complex structure of modes is a consequence of increasing thickness nonuniformity of effective field in thick dots. These "curled" modes become the lowest ones in azimuthal modes spectrum for $t > 50$ nm, and, in contrast with common uniform along dot thickness modes, have a significant difference in the intensity between clockwise (cw) and counterclockwise (ccw) modes of the same type.



Dynamical magnetization distributions of n=0,1,2 vortex eigenmodes.

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