Magnetic vortices dynamics in soft magnetic spherical shells

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1. Introduction

Nontrivial spin textures such as magnetic vortices [1] and skyrmions [2] have been intensively and extensively studied. Novel spin dynamic features including the gyration, azimuthal, and radial modes of vortices in magnetic elements [1] as well as the precession and reversal of vortex cores in nanospheres [3] and half-spheres [4] have been identified. Another distinctive geometry is spherical shells that have been experimentally synthesized [5] and studied on their static spin configurations using micromagnetic simulations [6]. However, the dynamic properties of magnetic vortices in spherical shells have yet been unveiled. In this study, we report on spin dynamic features of intrinsic eigenmodes found in spherical nano-shells, which are different from those of planar disk or square dots.

2. Results and Discussion

Using finite-element micromagnetic numerical simulations of permalloy spherical shells with an outer diameter of 100 nm and a shell thickness of 15 nm, we found two different magnetization states of parallel and anti-parallel vortex-core orientations in two vortex states placed on the north and south poles. Upon relaxing the two cores shifted from their equilibrium positions under external magnetic fields in the case of the parallel vortex cores, translational motions of the coupled two cores on the surface of the spherical shell appear. The two cores represent an out-of-phase motion about the static field direction with a large orbit distance and simultaneously a relatively fast in-phase motion about the core position with a small orbit distance. Using the Fast-Fourier-Transformations (FFTs), we found that the two vortices show two distinct eigenmodes at 80 MHz and 1.5 GHz that represent, respectively, a precession-like motion as in nano-spheres [3] and a gyration-like motion as in planar disks [7]. For the other case, anti-parallel vortex cores, the core motions show complex trajectories of the two vortices. Their FFTs reveal that both cores have their intrinsic gyration frequencies depending on the relative orientation between the core and the direction of static magnetic fields. However, there exist irregular trajectories because the two opposite cores have the same chirality about each core. This configuration is magnetostatically unfavorable in the simultaneous excitation of the two cores' resonant modes. This work provides a further understanding of dynamic-coupled motions of magnetic vortices in spherical shells.

3. References

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