Nanomagnetic Simulation of Interacting Magnetic Vortices in Rectangular Pattern

Dong-Hyun Kim*

BK21 Physics Program and Department of Physics, Chungbuk National University, Cheongju 361-763, South Korea

It has been discussed even in a textbook on magnetism that a very tiny ferromagnetic system prefers to form domain structures with a curling spin configuration to minimize a free-pole generation at boundaries and thus, to reduce a magnetostatic energy. In a ferromagnetic nanothin element, magnetic vortex structure with in-plane curling spins around out-of-plane core spins has long been theoretically predicted. Very recently this three dimensional vortex structure has been observed by means of magnetic force microscope [1] and spin-polarized scanning force microscope [2]. However, very few studies have been focused to an understanding of dynamic motion of such a magnetic vortex, while the magnetic vortex dynamics is a critical issue for its possible application for upcoming spintronics development. Very recently, it has been reported that the magnetic vortex exhibits gyrotropic core motion and the rotation sense of the moving vortex is mainly determined by the handedness of spin configuration of the vortex core [3]. Unfortunately, detailed mechanism of the gyrotropic vortex motion and the effect of the field strength on the vortex motion are still unclear. In this work, nanomagnetic simulation [4] is carried out for various sizes of permalloy rectangles having sizes of 0.5 x 1 to 2 x 4 μm^2 with double-Landau initial spin configuration. The field strength and its profile shape have been varied around resonance frequency (< GHz) determined by rectangle sizes. In this configuration, one can easily expect that the vortex will disappear from the magnetic rectangular patterns if the external field strength is strong enough to overcome the energy cost for kicking vortex out of patterns. On the other hand, if the field strength is weak, the magnetic vortex would be just perturbed from its equilibrium position, exhibiting its gyrotropic motion. Interestingly, in an intermediate range of an applied field, our simulation predicts bifurcation of a single vortex to multiple vortices, leading to that their complex motion cannot be simply described to be gyrotropic. It seems like that divided multiple vortices are exchanging their angular momenta via certain modes created by spin wave interactions.

Reference

[1] T. Shinjo *et al.*, Science **289**, 930 (2000).
[2] A. Wachowiak *et al.*, Science **298** 577 (2002).
[3] S.-B. Choe *et al.*, Science **304**, 420 (2004).
[4] M. J. Donahue and D. G. Porter, *OOMMF User's Guide*; http://math.nist.gov/oommf.

* E-mail: donghyun@chungbuk.ac.kr