Dynamic Symmetry Breaking in a Gyrotropic Motion of a Magnetic Vortex by DC-Spin-Polarized Current

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1. Introduction

A magnetic vortex has been attracted many interests owing to its applications to data storage and logic devices. Especially, it has been studied a spin-torque nano-oscillator based on self-sustained gyrotropic motion [1-3]. It is well-known that the initial magnetic vortex state influences only the shift of eigenfrequency for gyrotropic motion when a spin-polarized current is applied [2]. Recently, it is reported that the magnetic vortices are easily deformed along the thickness in relatively thick nanoelements [3-4]. In this work, we shows the symmetry breaking in the gyrotropic motion of magnetic vortex driven by spin-transfer torque (STT) accompanying with the Oersted field, which is completely different from well-known gyrotropic motion in thin nanoelements [2].

2. Simulations

In this work, we used a mumax^3 code [5] which is one of the micromagnetic simulation code to calculate the Landau-Lifshitz-Gilbert (LLG) equation including STT term: $d\mathbf{m}/dt = -|\gamma_L|[\mathbf{m}\times\mathbf{H}_{\mathrm{eff}}]+\alpha[\mathbf{m}\times(d\mathbf{m}/dt)]+\mathbf{T}_{\mathrm{STT}}$, where $\gamma_{L=}\ \gamma/(1+\alpha^2)$, which describes the dynamic motion of normalized magnetization $\mathbf{m}$, with the gyromagnetic ratio γ, the effective field $\mathbf{H}_{\mathrm{eff}}$, the saturation magnetization M_s, the Gilbert damping constant α. The STT term is given by $\mathbf{T}_{\mathrm{STT}} = \mathbf{m}\times[\mathbf{m}\times(\mathrm{u}\cdot\nabla)\mathbf{m}]+\beta\ \mathbf{m}\times(\mathrm{u}\cdot\nabla)\mathbf{m}$ where $\mathrm{u} = -Pj_e\mu_B/eM_s(1+\beta^2)$ where with non-adiabatic constant $\beta = 0.04$, the current density j_e, Bohr magneton μ_B, electron charge e, and the degree of spin polarization $P = 0.5669$. To apply out-of-plane spin-polarized current into an isolated permalloy (Py, $Ni_{80}Fe_{20}$) disk of diameter $2R$ = 300 nm and thickness L = 80 nm. The perpendicular polarizer which have downward spin-polarization is positioned below the disk.

3. Results and Discussions

We observed the deformation of the vortex core (VC) in an initial transient regime and it was affected by the chirality, the in curling direction of in-plane magnetization (**M**) of the magnetic vortex structure. For the case of clockwise (CW) chirality, VC is shrunk while it is expanded for the counter-clockwise (CCW) chirality. During the steady gyrotropic motion, a symmetry breaking was significant: the VC structure with CCW chirality was elongated much larger than it with CW chirality as shown in Fig. 1. Such a nontrivial dynamic symmetry breaking might comes from the difference of **M** configurations along the thickness direction according to the CW and CCW chiralities, which would affect the adiabatic STT. We will discuss deeply in the presentation.

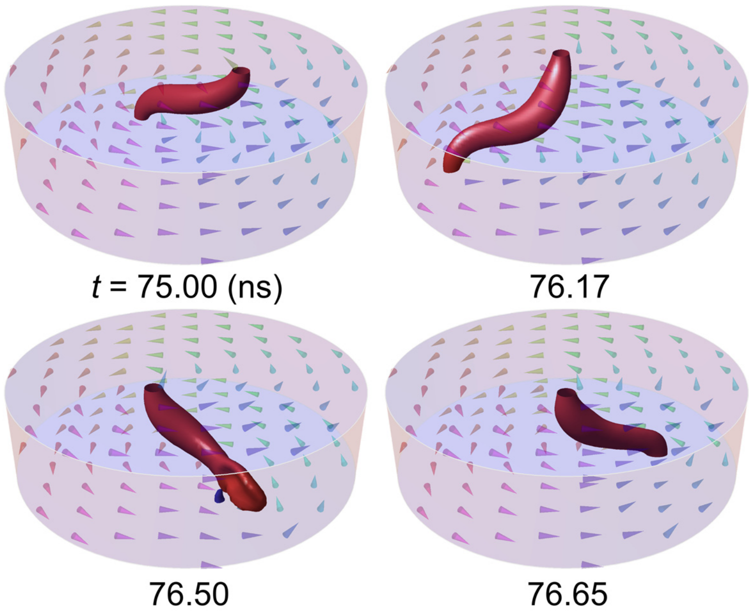

Fig. 1. The current-driven magnetic vortex dynamics for the CCW chirality.

4. References

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