Effect of Spin-diffusion on a Vortex Dynamics in a Nanodisk

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Landau-Lifshitz-Gilbert (LLG) equation with spin torque term (Eq. 1) is widely used for interpreting and understanding current-induced spin dynamics.

$$\partial M/\partial t = -\gamma M\times H+(\alpha/Ms)M\times(\partial M/\partial t)+u\cdot\nabla M-(\beta/Ms)[u\cdot(M\times\nabla)M] \quad \text{(Eq. 1)}$$

The first term describes the precession of the magnetization around the effective field (H) and the second term describes the damped motion of magnetization. The third and the last term are adiabatic and nonadiabatic spin-torque terms respectively. Theoretically, it is known that the dynamics of magnetic texture highly depends on the ratio between damping (α) and non-adiabatic parameter (β). It is reported that the value of β is controversial both theoretically [1-4] and experimentally [5-10]. Moreover, it is recently reported that the value of β is affected by the spin configuration which comes from spin-diffusion [13]. In order to understand the spin dynamics under complex spin texture, it is needed to study the effect of spin-diffusion on β.

In this work, we performed micromagnetic simulation using LLG equation with spin torque term, and spin-diffusion. The current-induced dynamics of a vortex core is micromagnetically modeled using a computational framework based on the fourth-order Runge-Kutta method. The model system is a circular Permalloy disk with the thickness of 20 nm and the diameter of 270 nm which is vortex favored dimension. The unit cell size is $1\times1\times20$ nm^3 on a two-dimensional grid. The a.c. current with the frequency of 605.5 MHz flows along the x-axis uniformly through the disk. The maximum current density is 1×10^7 A/cm^2. Standard material parameters for Permalloy are used: M_s=800 emu/cm^3, $\gamma=1.76\times10^7$ Oe^{-1}s^{-1}, α =0.01, P=0.7, and the exchange constant $A_{ex}=1.3\times10^{-6}$ erg/cm.

Fig. 1 shows the initial trajectory of a vortex core with different β and λ_{ex} (transverse spin-diffusion length). The symbols indicate the initial trajectory of a core without spin- diffusion. It is observed that the initial trajectory of a core is shifted upward as β increases [14]. The yellow and purple lines indicate the initial trajectory of a core with spin-diffusion. It is observed that there is a shift in trajectories just as there exists non-adiabatic spin torque even though the modeling was performed in the adiabatic limit. Estimated additional β originated from spin-diffusion is α (or 3α) for λ_{ex}=0.8 nm (or λ_{ex}=1.5 nm). The further studies will be discussed in detail.

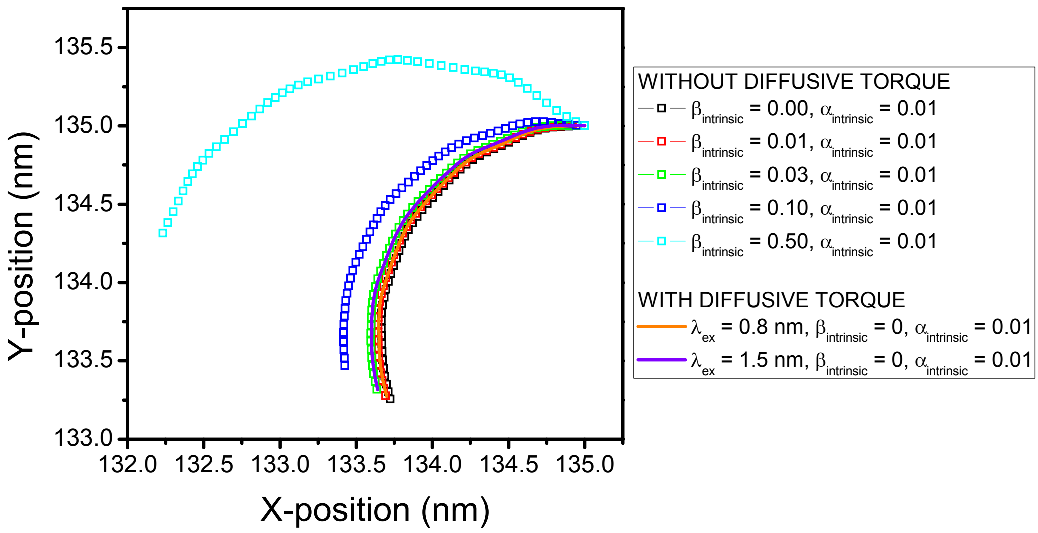

Fig. 1. Initial trakectories of a core with different λ_{ex} and β.

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