Emission of Electric Field by Spin-motive Force in a Nanodisk with Holes

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1. Introduction

The spin-motive force is a generalized electromotive force including a spin average of Berry phase [1]. This is a fundamental physical quantity in spintronics and thus a suitable model system to observe the spin-motive force is desired.

Yang et al. experimentally confirmed the spin-motive force by measuring the electromotive force induced by a moving domain wall (DW) in a nanostrip [2]. Yang et al. found that the voltage drop along the direction of the DW propagation and it is proportional to the transverse vortex motion and thus the frequency of anti-vortex injection. It is because the spin-motive force is described by the cross product of the spatial gradient of magnetization and its time derivative.

In this sense, the vortex gyration in a circular nanodisk is another plausible model system to observe the spin-motive force since it provides a nonzero value of the cross product between the spatial and temporal variations of the magnetization. However, the vortex gyration generally shows a sinusoidal function of the time and thus the time average of the electric field becomes zero, which causes a difficulty in experimental detection. By means of the micromagnetic modeling, we show pendulum motion of vortex core by introducing defects. It is possible to obtain a nonzero voltage from the vortex gyration and it is able to detect the spin-motive force.

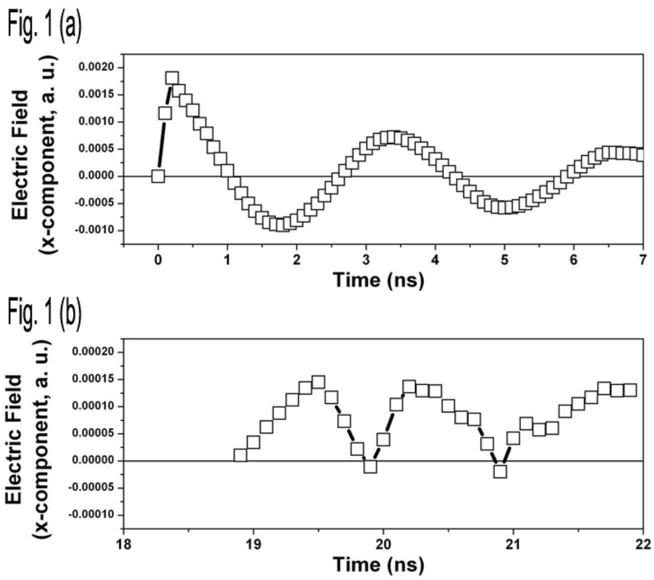
2. Micromagnetic Modeling

We perform micromagnetic simulation with the Landau-Lifshitz-Gilbert (LLG) equation. We assume a circular Permalloy disk with the thickness of 20 nm and the diameter of 270 nm. We simulate ac-magnetic-field induced vortex gyration motion in two model systems: Model I) no defect in the nanodisk and Model II) 4 holes in the nanodisk, whose positions are designed to make collisions between the vortex core and the holes [3].

3. Rsults and Discussions

Fig. 1 (a) shows the x-components of the spin-dependent electric field in the Model I. When the vortex core undergoes the gyration motion around the center of the nanodisk, the x-component of the core velocity changes its sign at every half cycle. However, the magnetization profile at the core does not change during the gyration unless the vortex core is reversed. As a result, the direction of electric field changes at every half cycle and thus the time-averaged electric field becomes zero.

In contrast, in the Model II with 4 holes, collisions between the vortex core and the holes happen under a proper bias condition, which provides periodic reversals of vortex core. In this case, the time-averaged spin-dependent electric field becomes nonzero (Fig. 1 (b)) and is thus experimentally detectable.



4. Summary

A model system allowing the experimental determination of the spin-motive force from the vortex gyration motion in a circular nanodisk is presented. It provide an easy experimental detection of the spin-motive force and thus an important tool to study the relationship between the charge and spin transports in ferromagnetic system.

5. References

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