Electric Field Induced by Spin-motive Force in a Perforated Nanodisk

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1. Introduction

The electromotive force is generated from the time-dependent variation of magnetic field, i.e. Faraday's law. The spin-motive force is a generalized electromotive force including a spin average of Berry phase [1]. It is highly needed to develop a suitable model system to observe the spin-motive force because it is one of fundamental physical quantities in spintronics.

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 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 is in general a periodic function of the time and thus the time average of the spin-motive force becomes zero, which causes a difficulty in experimental detection. By means of the micromagnetic simulation, we observe pendulum motion of vortex core by introducing defects, it is possible to obtain a nonzero voltage from the vortex gyration.

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 shows the x-component and y-component 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 it is expected that the time-averaged electric field becomes zero.

In contrast, in the Model II with 4 holes, there are collisions between the vortex core and the holes with a proper bias condition, which provides periodic reversals of vortex core. In this case, the time-averaged electric field becomes nonzero (Fig. 2) and is thus experimentally detectable.

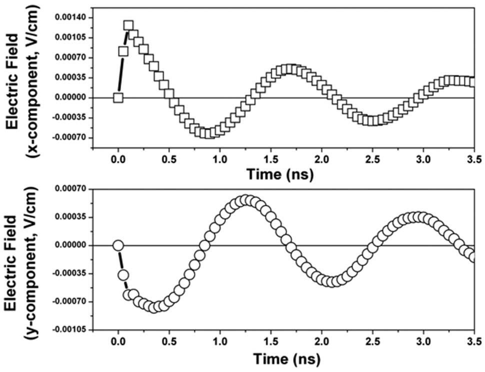

Fig. 1

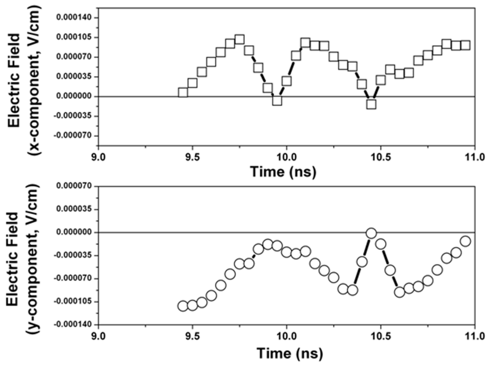

Fig. 2

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 can be one way to get experimental detection of the spin-motive force and it will provide an important tool to study the relationship between the charge and spin transports in ferromagnetic system.

5. References

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