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Phase control of spin waves traveling along magnetic nanowires using the Oersted fields induced by electric currents

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1. Introduction

Spin waves (SWs) traveling along magnetic nanowires at ultrafast speeds are highly promising for their applications to information processing as reliable signals [1-3]. Recently, Hertel *et al.* have reported on how to control the phase of SWs using magnetic domain walls that are positioned on the pass of traveling SWs [3]. However, it is not easy to practically manipulate the presence of well-established domain walls in magnetic nanowire waveguides. In this presentation, we report that the phase of spin waves is readily controllable with the Oersted magnetic fields induced by electric currents flowing directly along a conducting wire, as studied by micromagnetic simulations, for example, on a model system of the Mach-Zender-type interferometer.

2. Simulations

Micromagnetic simulations were performed using the OOMMF code [4] on a model system of the Mach-Zender-type interferometer, as illustrated in Fig. 1(a). This model system is composed of a bifurcated nanowire waveguide with 30 nm width and 10 nm thickness, and a conducting wire with 270 nm diameter. Electric currents flowing along the conducting wire induces the Oersted field around it, as displayed by the spatial distribution of its strength and direction, as shown in Fig. 1(b).

3. Results and Discussion

It is well known that the dispersion relation of SWs varies according to the strength and direction of an externally applied magnetic field. The fact allows us to manipulate the wavelength (or the phase) of SWs for a given frequency by the magnetic field induced by electric currents. As example, we designed the model system of a Mach-Zender-type interferometer, as shown in Fig. 1(b), where the same strength but opposite direction of a magnetic field induced by currents flowing a conducting wire leads to difference in the phases of separately traveling SWs passing each branch of the bifurcated nanowire waveguide. From the micromagnetic simulation results, the phase shift is found to be proportional to current density, J, in the conducting wire, as shown in Fig. 1 (c). Especially, for $J = 2\times10^{11}$ A/m^2, the amplitude of a SW packet passing at a position marked by "C" is strongly suppressed (Fig. 1 (d)), because the separately traveling SWs passing through different positions marked by "A" or "B" experience 180° out of phase with each other.

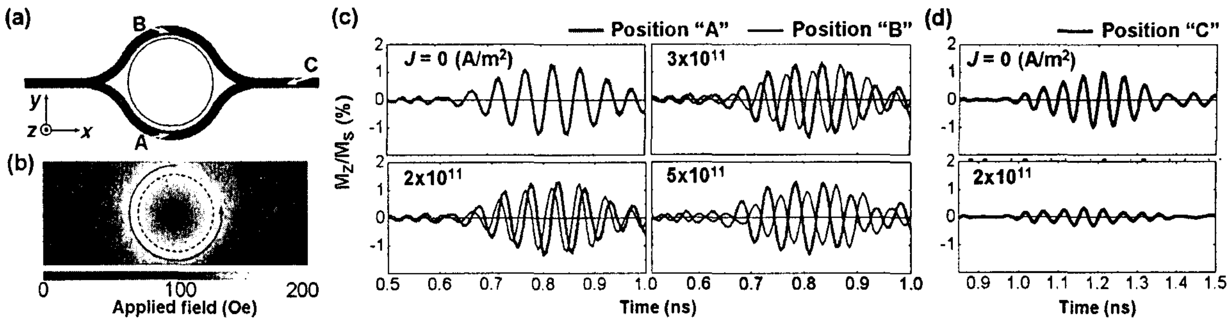

Fig. 1 (a) Model geometry for a spin-wave interferometer which is composed of a bifurcated nanowire waveguide with 30 nm width and 10 nm thickness (dark color), and a conducting wire with 270 nm diameter (gray color). The spatial distribution of the local Oersted field strengths is shown in (b) when current is flowing along the +z direction with $J = 2\times10^{11}$ A/m^2. The values of M_z/M_s are plotted as a function of time for various J values at two different "A" and "B" positions in (c) and those at a "C" position in (d).

4. Conclusions

We have demonstrated the possibility to control the phase of SWs using magnetic fields induced by electric currents flowing along a conducting wire. It is found that the phase shift of SWs varies with current density in the conducting wire, so that constructive and destructive interference can be manipulated by the magnitude of the current density. The present type spin-wave interferometer can be applicable to a magnetic logic gate such as NOT gate. This work was supported by Creative Research Initiatives (Research Center for Spin Dynamics & Spin-Wave Devices) of MOST/KOSEF.

5. References

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[4] For details, see http://math.nist.gov/oommf/.