FC05

Spin-wave Interferometer Controllable with the Oersted Fields Produced by Electric currents

Ki-Suk Lee and Sang-Koog Kim *

Research Center for Spin Dynamics and Spin-Wave Devices, Seoul National University, Seoul 151-744, Republic of Korea
Nanospintronics Laboratory, Department of Materials Science and Engineering, College of Engineering, Seoul National University, Seoul 151-744, Republic of Korea

*Corresponding author: sangkoog@snu.ac.kr, Phone: +82 2 880 5854, Fax: +82 2 885 1457

Spin waves (SWs) travelling 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 travelling 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 SWs is readily controllable with the Oersted magnetic fields produced 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 SW interferometer made of a Permally thin film, based on the knowledge obtained from theoretically and numerically calculated dispersion relations of SWs in the nanowires. The model system of the Mach-Zender-type SW interferometeris 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. Magnetic fields of the same strength but opposite directions are applied to each branch of the bifurcated nanowire waveguide. Since the dispersion relation of SWs varies according to the strength and direction of an externally applied magnetic field, the wavelength (or the phase) of SWs passing through each branch can be manipulated by the electric currents. From the theoretically or numerically obtained dispersion relation of SWs for given magnetic fields, we can manipulate the phase shift of SWs that were passed through each branch according to current density (J) in the conducting wire. As example, for $J = 2\times10^{11}$ A/m^2, the amplitude of SWs superimposed at a single pass after passing separately two different branches of the bifurcated nanowire waveguide is strongly suppressed, because they are 180°out of phase with each other. More details of the phase shift and their applications to logical gates will be presented.

This work was supported by Creative Research Initiatives (ReC-SDSW) of MOST/KOSEF.

REFERENCES

[1] K.-S. Lee, S. Choi, and S.-K. Kim, Appl. Phys. Lett. **87**, 192502 (2005).
[2] *S. Choi, K.-S. Lee, K. Yu. Guslienko, and S.-K. Kim, Phys. Rev. Lett.* **98**, 087205.(2007)
[3] R. Hertel, W. Wulfhekel, and J. Kirschner, Phys. Rev. Lett. **93**, 257202 (2004).

FC06

Magneto-optic Measurement of Nonlinear Ferromagnetic Resonance in Magnetic Thin Films

Thomas Gerrits[1]*, Pavol Krivosik[2,3], Michael L. Schneider[1], Carl E. Patton[2], T.J. Silva[1]

[1] National Institute of Standards and Technology, Boulder, Colorado, 80305, USA
[2] Department of Physics, Colorado State University, Fort Collins, Colorado, 80523
[3] Slovak University of Technology, 812 19 Bratislava, Slovak Republic

*Corresponding author: thomas.gerrits@nist.gov Phone: +1 303 497 4661, Fax: +1 303 497 3387

In recent years coplanar waveguide (CPW) techniques have been developed to study the ferromagnetic resonance (FMR) response in the time domain with step field excitation [1] and in the field or frequency domain with cw microwave excitation [2]. While CPW excitation technique is highly attractive for nonlinear dynamics studies, the time domain FMR response to fast rise time step fields does not appear to produce parametric spin waves or show Suhl instability effects, even when the dynamic magnetization deflection angles are in excess of 90° [3]. Recent time-resolved FMR measurements on Permalloy films made with large amplitude microwave pulses, however, do indicate a substantial increase in the apparent damping as well as a decrease in the spatially averaged magnetization [4]. Both effects can be taken as a manifestation of Suhl processes.

In this work, cw CPW microwave excitation at high power, in combination with a novel magneto-optic Kerr effect (MOKE) detection scheme, has been used to drive and make quantitative measurements of the nonlinear FMR response of a Permalloy thin film. The work was done for in-plane magnetized films and excitation frequencies from 1.25 to 3.75 GHz. From the calibrated MOKE response, it was possible to extract the critical precession angles at which the Suhl instabilities occur and map the quantitative nonlinear response above the Suhl threshold. Thesecritical angles were in the range of about 14°. The threshold microwave field amplitudes were consistent with fundamental relaxation rate considerations.

REFERENCES

[1] T. J. Silva, C. S. Lee, T. M. Crawford, and C. T. Rogers, J. Appl. Phys. **85**, 7849 (1999).
[2] S. S. Kalarickal, M. Wu, P. Krivosik, C. E. Patton, M. L. Schneider, P. Kabos, T. J. Silva and J. P. Nibarger, J. Appl. Phys. **99**, 093909 (2006)
[3] Th. Gerrits, T. J. Silva, J. P. Nibarger, and Th. Rasing, J. Appl. Phys. **96**, 6023 (2004).
[4] Th. Gerrits, M. L. Schneider, A. B. Kos, and T. J. Silva, Phys. Rev. B 73, 094454 (2006)