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Snell's law of the magnetostatic surface wave in ferromagnetic films

Kenji Tanabe[1], Ryo Matsumoto[2], Jun-ichiro Ohe[3], Shuichi Murakami[2], Takahiro Moriyama[4], Daichi Chiba[5], Kensuke Kobayashi[1] and Teruo Ono[4]

[1]Osaka University
Machikaneyama, Toyonaka, Osaka, 560-0043, Japan
[2]Tokyo Institute of Technology
Meguro-ku, Tokyo, 152-8551, Japan
[3]Toho University
Miyama, Funabashi, Chiba, 274-0072, Japan
[4]Kyoto University
Gokasho, Uji, Kyoto, 611-0011, Japan
[5]The University of Tokyo
Bunkyo-ku, Tokyo, 113-8656, Japan
Phone: +81-6-6850-5371 E-mail: tanabe@meso.phys.sci.osaka-u.ac.jp

Abstract

We present Snell's law of the magnetostatic surface wave in ferromagnetic films with a step structure [1]. Because the dispersion relation of the wave depends on the thickness, the step structure works as a junction between two areas with different dispersion relations. We observe that wavenumber of the wave is modulated at the step structure in order to satisfy Snell's law. Our studies are towards to a new field of spinwave optics.

1. Introduction

Recent technology developments in the micro-fabrication and the microwave technique enable us to excite the spin wave by using radio-frequency magnetic field. As magnon, which is a quasi-particle of the spin wave, has a potential for information processing, storage technology, and other microwave devices, a research field so-called "magnonics" is now attracting a lot of attention [2, 3]. To realize magnonics, we have to control the spin wave in circuits as we wish, which remains to be demonstrated at this moment. Therefore we should start with the spin wave control in a very simple system such as a junction.

Here we report that we successfully modulated the wavenumber of the magnetostatic surface wave (MSSW) [4] in a thin ferromagnetic film that consists of two regions with different thickness separated by a step. Because the dispersion relation of the spin wave depends on the thickness of the film, the step is regarded as a junction between two regions with different dispersion relations. When the spin wave propagates across the junction, the wavenumber of the spin wave is expected to be modulated in order to satisfy energy conservation law, namely Snell's law in optics.

2. Experiments

Our device is a wave guide for the spin wave with a junction between NiFe (Permalloy, Py) strips with 100 nm and 50 nm thicknesses (see Figure 1). We fabricate two gold coplanar waveguides on the Py strip to excite and detect the spin wave. A wave packet of the spin wave is excited in the Py strip with 100 nm thickness by using a pulse generator and is detected in the Py strip with 50 nm thickness by a digital oscilloscope [5]. The detected voltage signal is nothing but the wave packet propagating across the junction between the two Py strips with 100 nm and 50 nm thicknesses (see Figure 2).

We observed that wavenumber of the spin wave passing through the junction doubles reflecting the thickness difference. According to Snell's law, the relative refraction factor is defined as the phase velocity [6]. Because the dispersion of the MSSW depends on product of the wavenumber and the thickness, the relative refraction factor of the spin wave is proportional to inverse the thickness. As the spin wave propagates from the strip with 100 nm thickness into the strip with 50 nm thickness, the wavenumber is expected to double. The experimental results are in a good agreement with the theory.

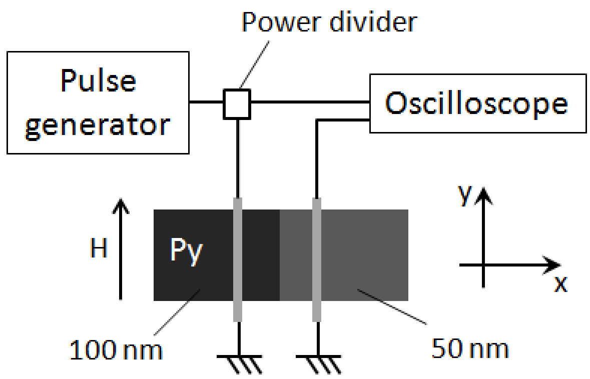

Fig. 1 Schematic diagram of the device structure and the measurement setup.

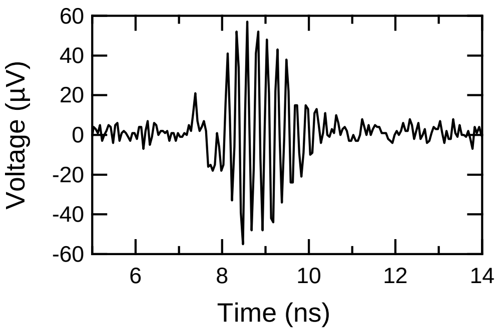

Fig. 2 The detected wave packet of the spin wave at H=200 Oe. This data indicates that the spin wave propagates from the strip with 100 nm thickness into the strip with 50 nm thickness. According to the dispersion relation of the MSSW, the wavenumber of the wave packet was found to be changed across the junction.

3. Conclusions

This work is the first experimental test of Snell's law of the spin wave. As Snell's law of the spin wave is important to understand the propagation of the spin wave or magnons such as in magnonic crystal, the present work to control the wavenumber of the spin wave will lead to the development of a new method in magnonics.

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References

[1] K. Tanabe, R. Matsumoto, J.-i. Ohe, S. Murakami, T. Moriyama, D. Chiba, K. Kobayashi1 and T. Ono, Appl. Phys. Express **7** (2014) 053001.
[2] A. A. Serga, A. V. Chumak and B. Hillebrands, J. Phys. D: Appl. Phys. **43** (2010) 264002.
[3] B. Lenk, H. Ulrichs, F. Garbs, and M. Munzenberg, Physics Reports **507** (2011) 107–136.
[4] D. D. Stancil and A. Prabhakar, "*Spin Waves Theory and Applications*" Springer
[5] M. Covington, T. M. Crawford, and G. J. Parker, Phys. Rev. Lett. **89** (2002) 237202.
[6] H. Xi, X. Wang, Y. Zheng, and P. J. Ryan, J. Appl. Phys. **104** (2008) 063921.