Nonreciprocity of Spin Wave with Small Wavenumber in Ferromagnetic Bilayer

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Spin wave has been attracting attention as a new information carrier due to its low energy consumption in propagation and high frequency response (GHz to THz) [1]. Especially, achieving unidirectional propagation of the spin wave is a crucial step for building blocks such as isolators and circulators, which are essential for data processing [2]. One approach for realizing this is to utilize frequency nonreciprocity. Whilst several systems have been proposed to induce frequency nonreciprocity, a ferromagnetic (FM) bilayer exhibits considerably large frequency difference despite its simple structure [3]. However, achieving significant nonreciprocity so far requires a large wavenumber, at which the group velocity tends to decrease as the dipole interaction becomes weaker and the fast Damon-Eshbach (DE) mode couples with the flat standing spin wave mode [4]. In this study, we investigated an influence of FM bilayer film thickness on frequency nonreciprocity as a function of wavenumber, which provides the guiding principle for achieving frequency nonreciprocity at small wavenumbers.

SiO_2 (50 nm)/MgO (3 nm)/Co (l/2 nm)/$Ni_{81}Fe_{19}$ (l/2 nm) was prepared on a SiO_2/Si substrate by using electron beam deposition (MgO, Co, $Ni_{81}Fe_{19}$) and RF magnetron sputtering (SiO_2), and coplanar waveguides (CPWs) of Au (100 nm)/Ti (3 nm) were equipped (see Fig. 1). Transmission spectra of spin waves (S_{21} and S_{12}) were measured by using a vector network analyzer (VNA), where the frequency range was set to be 300 kHz to 18 GHz with the power of 5 dBm. An external magnetic field was applied to the sample in the y direction and was swept from 0 mT to 100 mT. Figure 2(a) shows the colormap of $|\Delta S_{ij}|=|S_{ij} - S_{ij}\ (0\ \mathrm{mT})|$ (i, j = 1, 2 or 2, 1) when l = 100 nm, where the frequency difference of -1.04 GHz was obtained. The dispersion relations of several modes were calculated by using the Landau-Lifshitz equation [3], and the wavenumber and the mode of this spin wave were identified. The measurement result and the theoretical curves of different film thicknesses are plotted in Fig. 2(b), which indicates that strong nonreciprocity is realized at a small wavenumber. The detailed discussion will be given in the presentation.

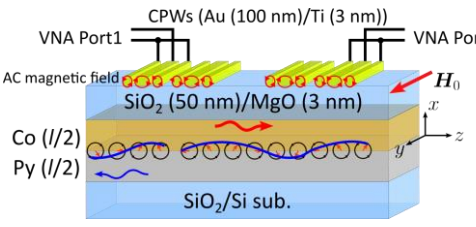

Fig. 1 Sample structure

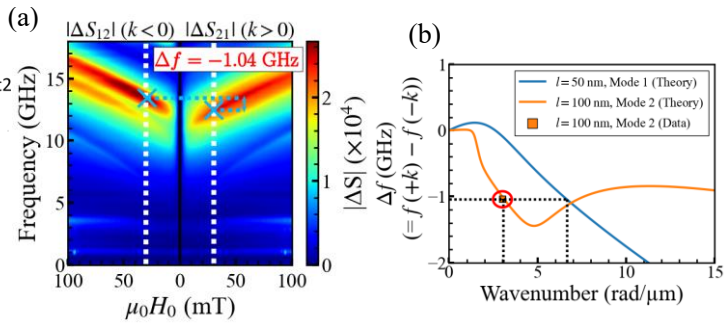

Fig. 2 (a) Colormap when l = 100 nm (b) Comparison of frequency nonreciprocity with different thicknesses ($\mu_0 H_0$ = 30 mT)

[1] A. Mahmoud *et al*., J. Appl. Phys. **128**, 161101 (2020). [2] D. Jalas *et al*., Nat. Photon. **7**, 579 (2013).
[3] M. Grassi *et al*., Phys. Rev. Appl. **14**, 024047 (2020). [4] M. Kostylev *et al*., J. Appl. Phys. **113**, 053907 (2013).