Large nonreciprocal frequency shift of propagating spin waves in synthetic antiferromagnets

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Introduction

Nonreciprocal spin wave propagation is of great interest for the realization of spin-wave-based logic circuits. It is known that spin wave packets excited by antennas exhibit different amplitudes depending on the relative direction between magnetization and microwave field [1]. In addition, asymmetric spin wave dispersion due to Dzyaloshinsky-Moriya interaction leads to nonreciprocal frequency shifts of propagating spin waves [2]. In this study, we observed large nonreciprocal frequency shifts of propagating spin waves in interlayer exchange-coupled synthetic antiferromagnets.

Experimental method

Ta (3 nm)/Ru (3 nm)/FeCoB (15 nm)/Ru (0.6 nm) /FeCoB (15 nm)/Ru (3 nm) were deposited on a thermally oxidized Si substrate by dc magnetron sputtering. From a magnetic hysteresis loop at 300 K, the canted magnetization configuration of two layers was confirmed in the low magnetic field region below the saturation field of approximately 1 kOe. The films were patterned into 50 μm×100 μm wires by EB lithography and Ar ion milling. Subsequently, 80-nm-thick SiO2 insulating layer was deposited by rf magnetron sputtering. Then, two coplanar waveguides consisting of Cr (5 nm)/Au (100 nm) were fabricated at the distance of 10 μm by EB lithography and evaporator. The propagating spin waves were measured using vector network analyzer at room temperature.

Experimental results

Figure 1(a) shows the propagating spin wave spectroscopy (PSWS) under the bias magnetic field H = 200 Oe, when the bias magnetic field is applied to the perpendicular direction of the microwave field, namely transverse pumping configuration as shown in the inset of Fig. 1(a). The different amplitudes depending on the propagation direction were observed due to nonreciprocal coupling between microwave fields and spin waves [1]. Figure 1(b) shows PSWS under H = 200 Oe, when the bias magnetic field is applied along the microwave field, namely longitudinal pumping configuration as shown in the inset of Fig. 1(b). Unlike the results in the case of transverse pumping configuration, a large nonreciprocal frequency shift depending on the propagating direction was observed in the case of longitudinal pumping configuration. This nonreciprocal frequency shift is attributed to the asymmetric spin wave dispersion due to dipolar contribution [3]. In the presentation, we will discuss the microscopic origin of the asymmetric spin wave dispersion in synthetic antiferromagnets.

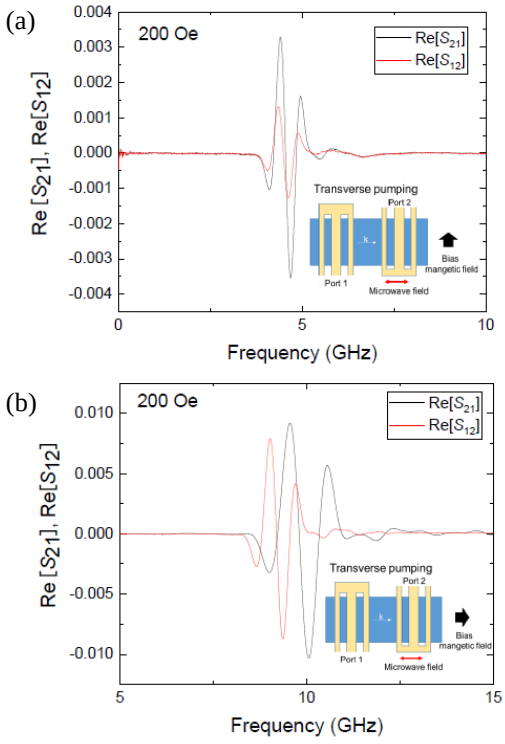

Figure 1: (a) Re[S_{21}] and Re[S_{12}] spectrum measured with transverse pumping configuration under 200 Oe. (b) Re[S_{21}] and Re[S_{12}] spectrum measured with longitudinal pumping configuration under 200 Oe.

Reference

1) V. E. Demidov *et al.*, Appl. Phys. Lett. 95, 112509 (2009).
2) J.-H. Moon *et al.*, Phys. Rev. B 88, 184404 (2013).
3) F.C. Nortemann *et al.*, Phys. Rev. B 47, 11910 (1993).