Investigation of origin of spin wave nonreciprocity

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Spin wave nonreciprocity, defined as the difference in characteristics depending on the propagation direction, provides functionality to magnonic devices. Spin wave nonreciprocity has primarily been studied using electrical measurements. However, it is difficult to identify the origin of nonreciprocity with this method because the signal contains contributions from both excitation and propagation effects. In addition, previous studies have focused only on specific magnetic field configurations. In this study, we use conventional electrical measurements and optical imaging measurements to observe the spatial distribution of spin waves while sweeping the magnetic field angle to investigate the origin of spin wave nonreciprocity [1].

We perform electrical measurements to study the angle dependence of spin wave nonreciprocity using the setup shown in Fig. 1(a). Transmission coefficients S_{21} and S_{12} are obtained by using a vector network analyzer (VNA) under an in-plane magnetic field H_{DC} at an angle θ. As shown in Fig. 1(b), the nonreciprocity κ_e, defined as the ratio of the amplitude of the transmission coefficients, increases around 10° and 30°. The theoretical nonreciprocity model κ_t, which considers only the asymmetry of spin wave excitation efficiency as the origin, explains the increase in the nonreciprocity κ_e around 10° but not around 30°, suggesting another origin of spin wave nonreciprocity: propagation asymmetry.

To confirm this hypothesis, we carry out magneto-optical Kerr effect (MOKE) measurements [2] to observe the spatial distribution of spin waves propagating along the $\pm x$ direction. We find that the propagation length asymmetry increases around 30°. Based on optical measurement results, the nonreciprocity κ', which considers both excitation and propagation asymmetry, reproduces the nonreciprocity κ_e over 30° in Fig. 1(b). These results indicate that spin wave nonreciprocity originates from both excitation and propagation asymmetry.

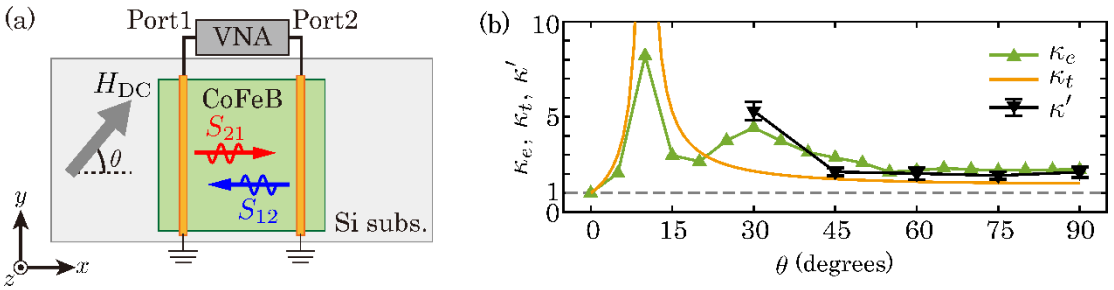

Fig. 1 (a) Experimental setup and device for observing spin wave nonreciprocity by electrical measurements. (b) Angle θ dependence of the nonreciprocity κ_e, κ_t, and κ' at 50 mT.

[1] H. Komiyama *et al.*, J. Magn. Soc. Jpn., **49**, 13-16 (2025).
[2] Y. Shiota *et al.*, Appl. Phys. Lett., **116**, 192411 (2020).