Coupling between acoustic and optic magnons in synthetic antiferromagnets

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Synthetic antiferromagnets consist of two or more ferromagnetic layers separated by nonmagnetic layers. When the magnetizations are coupled antiferromagnetically through the interlayer exchange coupling, this enables us to investigate the antiferromagnetic resonance modes; an acoustic mode (in-phase precession) and an optic mode (out-of-phase precession). Recently, an anti-crossing gap of ferromagnetic resonance (k = 0 μm^{-1}) between acoustic and optic modes, so-called magnon-magnon coupling, was reported in the layered antiferromagnet of $CrCl_3$[1]. In this study, we observed the anti-crossing gap of spin wave resonance ($k \neq 0$ μm^{-1}) between acoustic and optic modes in synthetic antiferromagnet of FeCoB/Ru/FeCoB.

The films were prepared by sputter deposition on a thermally oxidized Si wafer: Ta(3)/Ru(3)/$Fe_{60}Co_{20}B_{20}$(15)/Ru(0.6)/$Fe_{60}Co_{20}B_{20}$(15)/Ru(3) (thickness in nm). The two in-plane magnetized FeCoB layers separated by a Ru layer with a thickness of 0.6 nm were antiferromagnetically coupled through the interlayer exchange coupling. The films were micro-fabricated to spin wave devices, as shown in inset of Fig. 1. The efficiently excited spin wave wavenumber k was determined by the design of coplanar waveguides (CPWs). The scattering parameter S_{11} for reflection was measured by a vector network analyzer connected to the CPWs. The external magnetic field was applied at an angle φ_H with respect to the spin wave propagation direction.

Figure 1 shows the Re[S_{11}] spectra as a function of magnetic field. When φ_H = 0, 90 deg. (Fig. 1(a)(c)), spin wave resonance frequencies of acoustic and optic modes are degeneracy at their crossing point and there is no anti-crossing gap. On the other hand, when φ_H = 45 deg. (Fig. 1(b)), two resonant modes are hybridized and the anti-crossing gap is generated. This is due to the interaction between two ferromagnetic layers through the magnetostatic dipole fields generated by spin waves. In the presentation, we will discuss more detail about φ_H and k dependence of anti-crossing gap, and provide a quantitative description of coupling strength.

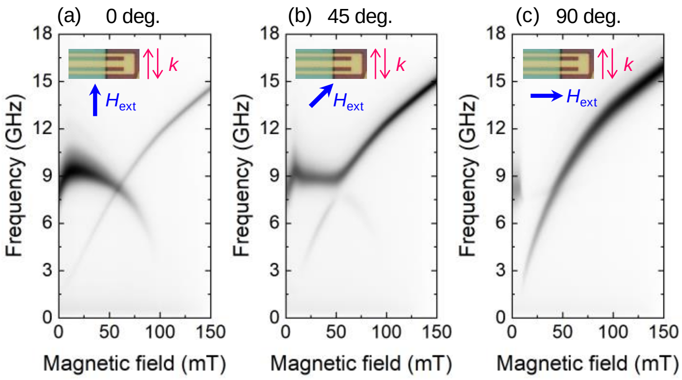

Fig. 1 Two-dimensional map of Re[S_{11}] spectra as a function of magnetic field with k = 1.2 μm^{-1} for φ_H of (a) 0 deg. (b) 45 deg. and (c) 90 deg.

[1] D. MacNeill et al., arXiv: 1902.05669 (2019)