Strong magnon-magnon coupling in synthetic antiferromagnets

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Spin waves and their quasiparticles, i.e., magnons, can be used as information carriers and for information processing[1-3]. Hybrid quantum systems based on magnon have been intensively studied in the last decade, because these systems offer a promising platform for novel quantum information technologies[4]. It has been recently reported that an anticrossing gap between two magnetic resonances, so-called a magnon-magnon coupling, can be realized in several kinds of systems[5)-8)], which is analogous to the hybrid quantum system. However, most of experiments focused on magnons with uniform precession ($k = 0.0\ \mu\mathrm{m}^{-1}$, where k is the wave number). In this study we demonstrate the strong magnon-magnon coupling between acoustic and optic modes by utilizing magnons with nonuniform precession ($k \neq 0.0\ \mu\mathrm{m}^{-1}$) in ferromagnetic-metal-based synthetic antiferromagnets (SAFs) of FeCoB/Ru/FeCoB[9].
Figures 1(a)-1(c) shows the spin wave resonance spectra ($k = 1.2\ \mu\mathrm{m}^{-1}$) at $\varphi_k = 0°, 45°,$ and $90°$, where φ_k is the angle between an external magnetic field and the spin wave propagation direction. The anticrossing gap g/π between two modes appears when the spin wave propagates in the direction of $\varphi_k \neq 0°$ and is maximized at approximately $\varphi_k = 45°$. We found that the coupling strength is larger than the dissipation rates for both the resonance modes. Therefore, strong coupling regime is achieved in this study. A theoretical analysis shows quantitative agreements with the experimental results and indicates that the appearance of the anticrossing gap accompanies symmetry breaking with respect to the exchange of magnetizations due to dynamic dipolar interaction generated by the magnetization motion of spin waves. Our study offers a new approach toward tunable magnon-magnon coupling systems for SAF-based magnonic applications.

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Reference

1) V.V. Kruglyak *et al., J. Phys. D. Appl. Phys.* **43**, 264001 (2010)
2) A. Khitun *et al., J. Phys. D. Appl. Phys.* **43**, 264005 (2010)
3) A.V. Chumak *et al., Nat. Phys.* **11**, 453-461 (2015)
4) D. Lachance-Quirion *et al., Appl. Phys. Express* **12**, 070101 (2019)
5) S. Klingler *et al., Phys. Rev. Lett.* **120**, 127201 (2018)
6) J. Chen *et al., Phys. Rev. Lett.* **120**, 217202 (2018)
7) D. MacNeill *et al., Phys. Rev. Lett.* **123**, 047204 (2019)
8) L. Liensberger *et al., Phys. Rev. Lett.* **123**, 117204 (2019)
9) Y. Shiota *et al., Phys. Rev. Lett.* **125**, 017203 (2020)

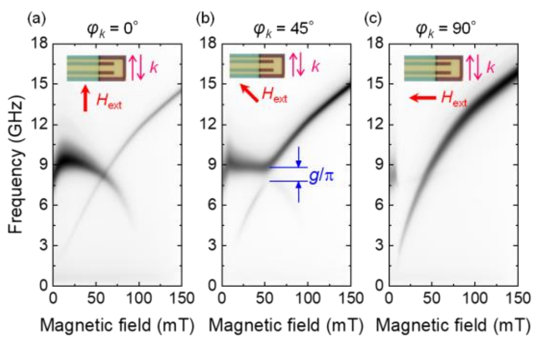

Fig. 1 Contour plots of Re[S_{11}] for spin wave resonance spectra ($k = 1.2\ \mu\mathrm{m}^{-1}$) at (a) $\varphi_k = 0°$, (b) 45°, and (c) 90°.