Slow-Wave Hybrid Magnonics

Xufeng Zhang
Northeastern University, Boston, USA

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Cavity magnonics[1] represents a burgeoning research frontier that explores the interaction between magnons and cavity photons. Such platforms hold unique advantages by combining the strengths of both magnonic and microwave systems, promising applications in quantum transduction, dark matter detection, and neuromorphic computing. However, cavity magnonics relies on the enhancement effect of microwave resonances to achieve coherent interaction, which is inherently narrowband and thus limits the operational bandwidth. In practical applications, it is highly desired to develop non-resonant structures that support traveling photons to achieve large bandwidths for magnon-photon interaction without sacrificing the coupling strength, but it is extremely challenging due to the lack of cavity enhancement. This challenge is particularly pronounced in integrated devices where micro/nano-magnonic devices interface with microstrips or coplanar waveguides (CPWs).

To tackle this challenge, we introduced a novel concept termed slow-wave hybrid magnonics in our recent work[2]. Previously, slow lights have been employed to enhance light-matter interactions and introduce new functionalities in optics. By incorporating spoof surface plasmon polariton (SSPP) structures, we extended the concept of slow waves to microwave photons and, for the first time, merged the two promising fields – spoof plasmonics[3] and cavity magnonics[1] – into a new platform that enabled broadband hybrid magnonic interactions. Importantly, large coupling strengths were achieved on such travelling-wave (non-resonant) platforms, facilitating intricate system dynamics crucial for complex magnonic systems such as magnonic crystals and networks. More interestingly, a new phenomenon of slow-wave strong coupling was observed on our platform. In addition, we demonstrated an example application of slow-wave hybrid magnonics in studying broadband magnon-phonon interactions.

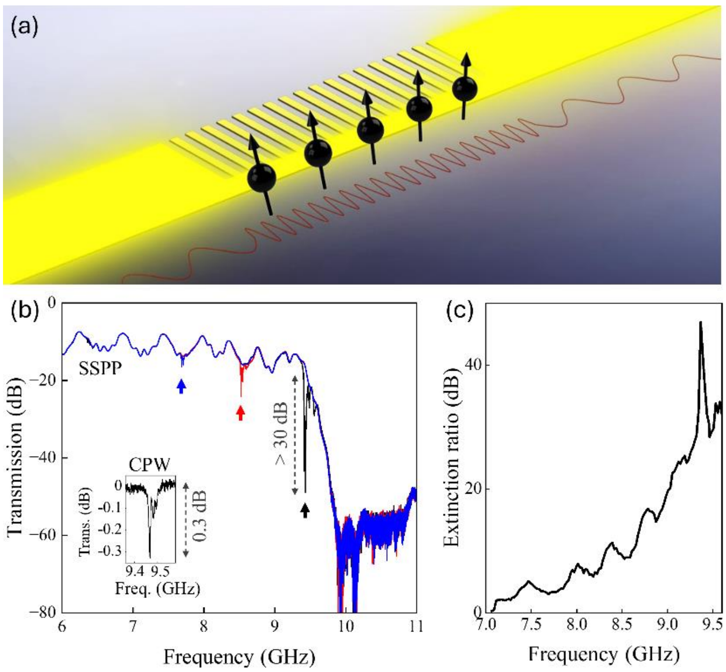

Fig. 1. (a) Schematics of the SSPP-magnon coupled system. (b) Typical transmission spectra of the SSPP waveguide loaded with a magnonic resonator made of a piece of yttrium iron garnet (YIG) thin film. Three transmission curves are overlaid, corresponding to three different magnon frequencies (bias fields), as indicated by the dips near 7.7, 8.5, and 9.4 GHz, respectively. Extinction ratio over 30 dB is achieved at 9.4 GHz, indicating drastically enhanced SSPP-magnon coupling. Inset shows the magnon signal measured on a coplanar waveguide (CPW) which has an extinction ratio of only 0.3 dB. (c) Summary of the magnon extinction ratio as a function of magnon frequency, with the maximum value exceeding 40 dB.

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[1] B. Rameshti, et al, Phys. Rep. 979, 1 (2022); Y. Li, et al, J. Appl. Phys. 128, 130902 (2020).
[2] J. Xu, … X. Zhang, Phys. Rev. Lett. 132, 116701, (2024).
[3] F. Garcia-Vidal, et al, Rev. Mod. Phys. 94, 025004 (2022).