Exciting skyrmion dynamics through higher-order spin-wave modes

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The interaction of propagating spin waves with spin textures, particularly with skyrmions, is an interesting research topic in magnetism, particularly in magnonics. It also provides the opportunity for control spin-wave propagation and brain-inspired computing systems.

A three-layered hybrid system with zero magnetic field was investigated using micromagnetic simulations. It combines a permalloy waveguide with a thin circular nanodot with a stable Néel-type skyrmion made of material with perpendicular magnetic anisotropy and Dzyaloshinskii-Moriya interactions, as well as a layer of nonmagnetic separation. Throughout this study, we examined (i) the static coupling between the nanodot and waveguide, [1] (ii) whether propagating spin waves could be used to induce skyrmion dynamics, (iii) the effects of a skyrmion in nanodot on spin-wave transmission through a waveguide [2]. Shape anisotropy maintains magnetic saturation along the waveguide's long axis. Magnetic interactions between a nanodot and a waveguide result in a skyrmion imprint below the nanodot. Through this mutual interaction, the skyrmion in the nanodot loses its circular symmetry and becomes deformed. Long spin-wave propagation is enabled by our system, which combines a waveguide and a nanoresonator. The presence of skyrmion in nanodot and imprint in waveguide affect spin-wave flow.

Using broadband excitation, we studied spin-wave transmission over a wide range of frequencies. A skyrmion and its imprint affect the transmission spectrum differently. Imprint at low frequencies exhibit significant amplitude, meanwhile, skyrmion excitations become dominant around 10 GHz. Excitation of the skyrmion leads to appearing of azimuthal modes at the edge and standing waves in the skyrmion core. Moreover, the skyrmion stimulates very low-frequency modes by coupling with higher-frequency modes, which origin is still under debate. Due to coupling with the nanodot, these excitations are also visible in the imprint spectrum.

In order to control spin waves, we have found that coupling them to the resonant modes of the skyrmion-imprint hybrid system is a viable approach, making it a promising technique for various applications.

References:

[1] M. Zelent, et al., arXiv:2204.05620v1 [cond-mat.mes-hall] (2022)
[2] K. A. Kotus, et al., APL Materials, 10 (9), 091101 (2022)

The research has received funding from the Polish National Science Centre, projects nos UMO-2018/30/Q/ST3/00416 and UMO-2020/37/B/ST3/03936