Scattering of spin waves in the single-mode and multi-mode ferromagnetic waveguide

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Most of the research involving the skyrmion-waveguide system has focused on the stabilization, dynamics, and motion of the skyrmion within the waveguide. However, in our work we decided to present a slightly different approach, we studied the propagation of spin waves in a waveguide under the influence of a skyrmion located above the waveguide.

Assuming magnetization along the waveguide, we investigate the backward volume magnetostatic spin-wave modes via micromagnetic simulations how the spin waves excited in the waveguide are affected by the heterogeneity of magnetization in the nanodisk with a skyrmion, placed above the waveguide. Based on the obtained results we conclude that in a single-mode and a multi-mode waveguide, the introduction of skyrmion into the system influences the propagation of spin waves, e.g. causes scattering into other modes. The scattering process depends on the frequency and the eigenspectra of the spin-wave oscillations in the skyrmion.

By examining the dipole coupling between the spin-wave and the dynamics of the skyrmion, we observed the conversion of incident homogeneous mode to the quantized by width spin-wave modes. Interestingly, at a low frequency, we observed the skyrmion-induced magnetic field heterogeneity reflects the spin-wave energy in the waveguide, creating a reflected mode with two nodal lines. The presented mechanism of spin-wave mode conversion in a ferromagnetic waveguide can be useful for nanoscale control of the propagating spin waves.

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