Magnon Induced Reversal, Steering, and Interference in Ferromagnet/Ferrimagnet Hybrid Structures

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Spin-wave based computing gains increasing interest [1]. Recently, a nanoscale neural network was proposed which made use of interfering spin waves (magnons) in yttrium iron garnet (YIG) below an array of ferromagnetic nanomagnets [2]. However, the assumed magnon steering and multi-directional interferometry of coherently scattered short-wave magnons had not been experimentally verified. The so-called extinction ratio which is relevant for binary 1/0 output operations was not known either. Hence, experimental evidence is urgently needed to substantiate the prospects of unconventional computing schemes in nanomagnonics.

We have explored the excitation, transmission and interference of short-wave magnons in YIG films with different thicknesses ranging from 11 and 113 nm. The YIG was covered by different arrays of ferromagnetic nanostructures such as nanostripes [3,4] and nanopillars [5]. The YIG was grown by liquid phase epitaxy on GGG. The ferromagnet was 20-nm-thick polycrystalline $Ni_{80}Fe_{20}$ (Py). We integrated coplanar waveguides with magnonic grating couplers to coherently excite magnons in the GHz frequency regime with wavelengths λ from about 49 nm to a few $_{\mu}$m. For excitation and detection we used a vector network analyzer (VNA) and micro-focus Brillouin (inelastic) light scattering.

Magnons propagating in YIG underneath periodically and aperiodically arranged nanopillars evidenced multi-directional magnon steering into numerous on-chip directions. The extinction (on/off) ratios which we evaluated from interference experiments showed unprecedentedly high values of 26 ($\pm$8) dB [31 ($\pm$2) dB] for magnons with $\lambda =$ 69 nm (154 nm) [5]. They were obtained over macroscopic propagation lengths of 350 x λ. Experiments involving nanostripes on YIG showed magnon transmission spectra which depended characteristically on the VNA power in the linear excitation regime. We attributed the observation to magnon-induced reversal of Py nanostripes when biased at a small opposing field [4]. We will report on further studies based on different nanomagnets on YIG. In these samples we observed magnon-induced reversal at different threshold amplitudes. For the 11-nm-thick YIG, we found a group velocity asymmetry of counterpropagating magnons which we attributed to Dzyaloshinskii-Moriya interaction similar to Ref. [6]. Our work fuels the experimental realization of magnon-based neural networks and in-memory computation.

References:

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