Spin-wave dynamics in crescent shape nanorods

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Nanowires are an exciting area of research and promising structures for applications. This is due to their small size, which allows dense packing and interesting properties rarely found in bulk systems. Their properties depend not only on the cross section size, but are also influenced by their shape, especially when used for conducting waves. For spin waves it also depends on the magnetization configuration. We present the results of our preliminary studies of spin waves in ferromagnetic rods with crescent-shaped cross sections and nanoscale dimensions, the structures that can be fabricated by depositing ferromagnetic material on the curved non-magnetic substrate. We show that these nanorods have different spin-wave modes covering a wide frequency range, which can be controlled by the amplitude and orientation of the external magnetic field, B_{ext} [1]. We consider propagation along the nanorod axis (Fig. 1) as well as perpendicular to it when the array of nanorods is formed (Fig. 2). For the first case, we show the ferromagnetic resonance spectra and the transmission channels formed by different modes with a nonreciprocal dispersion relation. Interestingly, when the bias magnetic field is perpendicular to the nanorod axis, the sign of the nonreciprocity, i.e. the sign of $\delta f(k_z) = f(k_z) - f(-|k_z|)$ where f is the spin wave frequency and k_z is its wavenumber, depends on the mode type and moreover on the value of $|k_z|$. In the second case, when the bias field is along the nanorod axis, the inherent nonreciprocity of the system is abolished when every second rod is reversed. We show with the simple arguments based on the theoretical model that these properties are due to different top and bottom surfaces, and the interplay of magnetostatic interactions and ellipticity of the precession, apart from standard confinement effects. We discuss the potential usefulness of crescent-shaped nanorods for magnonic applications.

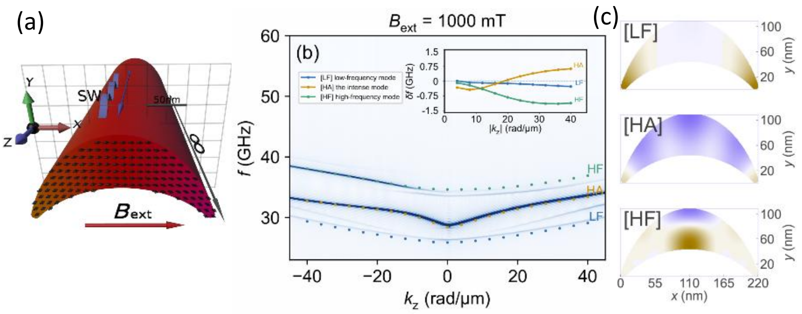

Fig. 1. (a) Crescent-shape nanorod under investigation. (b) Dispersion relation of spin waves in a single nanorod. Inset: $\delta f(k_z)$ for selected modes shown in (c). (c) Dynamic magnetization field distribution of the selected spin-wave mods and $k_z = 0$.

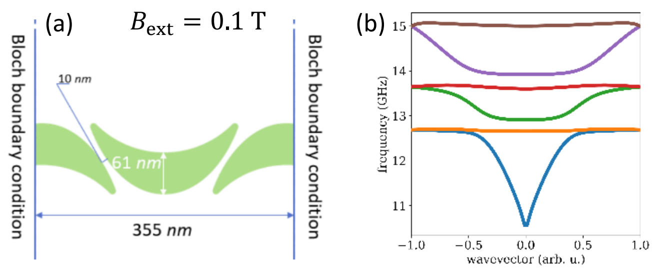

Fig. 2. (a) Cross-section of the array of the crescent-shape nanorods, and (b) the dispersion relation of spin waves propagating perpendicular to the nanorod axis, i.e., along the array periodicity.

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[1] M. Gołębiewski, H. Reshetniak, U. Makartsou, M. Krawczyk, A. van den Berg, S. Ladak, and A. Barman, Spin-Wave Spectral Analysis in Crescent-Shaped Ferromagnetic Nanorods, Phys. Rev. Appl. 19, 064045 (2023)