Generation of Short-Wavelength Spin Waves in an Antidot Lattice via a Nonlinear Process

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The development of information technology is characterized by faster, miniaturized and more efficient information processing to meet the growing expectations of modern society. Since the frequency range of spin waves is from a few GHz to a few hundred GHz, and the corresponding wavelengths are very short, from micrometers to a few nm, magnonics can be useful there. Therefore, conversion methods are sought that allow the microwave field excitation of very short spin waves, and high frequencies, e.g. those used in wireless and cellular transmission ranges (including future 6G technologies), i.e. from 1 GHz to 100 GHz. In recent years, the conversion of microwaves into short spin waves with wavelengths well below 100 nm has been demonstrated. However, the frequencies of these waves are typically well below 10 GHz. We present promising approaches recently developed in our group to excite high frequency (above 20 GHz) and very short wavelength (even below 50 nm) spin waves. We propose to exploit three-magnon nonlinear processes occurring in the magnonic crystal under microwave magnetic field excitation to induce second (third) frequency harmonics of very short wavelengths. Using micromagnetic simulations, we analyze two scenarios where the microwave field pumps a spin-wave mode confined to the cavity of the antidot lattice [1] or a mode localized at the edge of the antidots. In the first scenario, the frequency of the cavity mode is equal to the ferromagnetic resonance frequency of the planar ferromagnetic film, which overlaps with the magnonic bandgap of the magnonic crystal, providing an efficient mechanism for confinement and magnetic field tunability. In the second scenario, the edge mode frequency is below the bulk band and naturally allows for high confinement of the spin wave amplitude. In both approaches, we demonstrate the generation of high-frequency harmonics of the fundamental cavity mode, or edge spin waves, when the amplitude of the pumping microwave field exceeds a threshold. We show that the intensity of n harmonics scales linearly with the field intensity to the n-th power and inversely with the static magnetic field and is weakly dependent on the geometry of the microwave microstrip used for excitation.

[1] Nikhil Kumar, Paweł Gruszecki, Mateusz Gołębiewski, Jarosław W. Kłos, and Maciej Krawczyk, *Exciting high-frequency short-wavelength spin waves using high harmonics of a magnonic cavity mode*, Adv. Quantum Technol. 2024, 2400015 (2024).

This work was supported in part by the National Science Center Poland project OPUS-LAP no 2020/39/I/ST3/02413.