Magnon Interactions in Antidot Lattices with Perpendicular Magnetic Anisotropy

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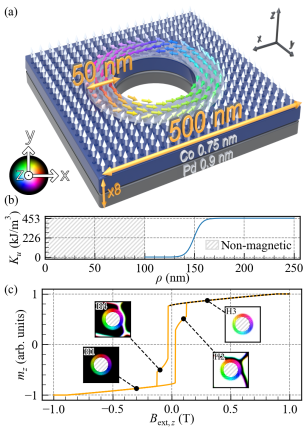
Magnonic crystals (MCs) are magnetic meta-materials able to control spin-waves (SWs). These MCs, made from various material combinations like ferromagnetic dots in non-magnetic matrices or antidot lattices (ADLs), guide SWs and have diverse applications.Recent studies emphasize strong magnon-magnon coupling in nanomagnonic devices, vital for advanced designs, with tunable coupling strength via external parameters [1]. Our research shows multilayer ADLs with perpendicular magnetic anisotropy (PMA), such as [Co/Pd]8 multilayers, influencing SW propagation through periodic magnetization texture [2]. Micromagnetic simulations identified low-frequency modes in ADLs affected by ion beam patterning, which modifies the antidot rim, reducing PMA in these areas [3,4].We investigate the SW spectra in ADLs with modified rims (ADL-MR) and the effects of external magnetic field strength. In ADL-MR, different magnetization states in bulk and rim emerge under an out-of-plane magnetic field. At remanence, while the bulk maintains out-of-plane saturation, the rim forms a vortex-like state. Field switching leads to domain wall formation in the bulk, with the rim reaching full saturation under high field intensities.Our analysis includes a ring lattice (RL) without PMA and a simplified ADL with PMA but no rims. The ADL shows a linear SW frequency-field relationship with no mode interaction. In the RL, low frequency curves at zero field represent low order azimuthal modes, degenerating from clockwise and counterclockwise modes, and split as the field increases.In ADL-MR, first-order radial rim modes at low frequencies exhibit strong bulk interaction, transitioning modes from bulk to rim with increasing field due to rim-bulk exchange interactions. Higher frequency second-order radial rim modes in ADL-MR show bulk mode hybridization, leading to gaps and non-linear frequency-field dependencies. This magnon-magnon coupling, primarily driven by exchange interactions, is quantified by high cooperativity values.Comparative simulations with a spacer layer between rim and bulk in ADL-MR highlight the exchange interaction's role in azimuthal modes. Our findings reveal unique coupling mechanisms in ADL-MR, indicating a new dynamic coupling type between non-collinear magnetization regions, mainly through exchange interactions. This insight advances magnonic device design with tunable coupling strengths and frequencies.



Evolution of the SW resonance spectra for the RL, ADL, and ADL-MR in dependence on the external out-of-plane magnetic field. The color intensity corresponds to the maximum amplitude value of the SW spectra. In the insets, the hue gives the in-plane orientation of the magnetization and the saturation gives the spatial amplitude. The circular dashed line represent the outer edge of the modified rim. The color of the inset borders indicate which geometry it belongs to. The non-magnetic areas are hatched in gray.

References

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