Spin-wave bandgap engineering via mode hybridization in dipolarly coupled YIG film-CoFeB nanodisk magnonic crystals

J. Hyun,[a] K. Szulc,[b,c,d] M. Zelent,[c,e] N. Kuznetsov,[a] L. Flajšman,[a] M. Krawczyk,[c] P. Gruszecki,[c] A. Gopakumar,[f] C. Dubs,[f] and S. van Dijken[a]

a: Department of Applied Physics, Aalto University, Espoo, Finland;
b: Institute of Molecular Physics, Polish Academy of Sciences, Poznań, Poland;
c: Faculty of Physics and Astronomy, Adam Mickiewicz University, Poznań, Poland;
d: CEITEC BUT, Brno University of Technology, Brno, Czechia;
e: achbereich Physik and Landesforschungszentrum OPTIMAS, Rheinland-Pfälzische Technische Universität Kaiserslautern-Landau, Kaiserslautern, Germany;
f: INNOVENT e.V. Technologieentwicklung, Jena, Germany.

We investigate spin-wave transport in hybrid two-dimensional magnonic crystals comprising a low-damping yttrium iron garnet (YIG) film coupled to periodic arrays of CoFeB nanodisks. Using propagating spin-wave spectroscopy, super-Nyquist magneto-optical Kerr effect microscopy, and micromagnetic and finite-element simulations, we demonstrate the emergence of pronounced and tunable transmission gaps that do not originate from conventional Bragg backscattering. Instead, the gaps arise from hybridization between the fundamental propagating mode in the YIG film and in-plane transverse standing spin-wave modes induced by the periodic nanodisk array. The strength and spectral position of these gaps are controlled by geometric parameters and by the magnetic state of the nanodisks, which governs both static and dynamic dipolar coupling. In particular, switching between the S state and vortex state strongly alters spin-wave transmission via induced shifts in the coupled mode dispersions (Fig. 1). For larger lattice periods, additional gaps emerge due to interactions with modes quantized transverse and along the propagation direction, reflecting dispersion folding in two dimensions. Our results establish mode hybridization as a versatile mechanism for engineering spin-wave band structures beyond the constraints of Bragg scattering and provide a pathway toward reconfigurable magnonic devices based on dipolarly coupled hybrid architectures.

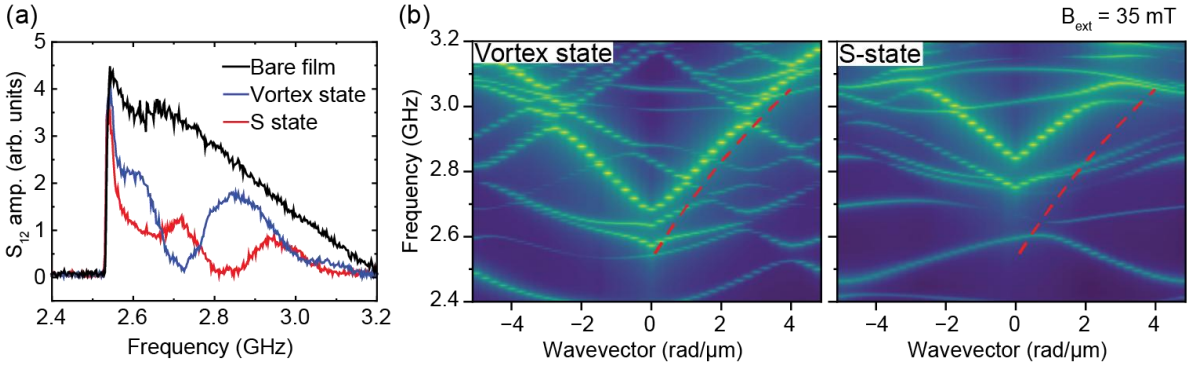

Fig. 1. (a) Spin-wave transmission spectra at an applied magnetic field of 35 mT. The black curve corresponds to a bare YIG film, whereas the blue and red curves show the same YIG film coupled to a CoFeB nanodisk array in the vortex and S state, repectively. (b) Spin-wave dispersion relations for the YIG film with CoFeB nanodisks in the vortex and S states at the same field. The dispersion of the bare YIG film is indicated by the red dashed lines.

This project has received funding from the European Union's Horizon Europe research and innovation program under Grant Agreement No. 101070347-MANNGA. However, views and opinions expressed are those of the authors only and do not necessarily reflect those of the European Union or the European Health and Digital Executive Agency (HADEA). Neither the European Union nor the granting authority can be held responsible for them. We also acknowledge financial support from the Jane and Aatos Erkko Foundation, the Technology Industries of Finland Centennial Foundation, and the Research Council of Finland (Project No. 357211).