FERROMAGNETIC-SUPERCONDUCTING HYBRIDS FOR LOCAL CONTROL OF MAGNETIZATION CONFIGURATION AND DYNAMICS,

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One of the key challenges in magnonics is achieving local control over both the static magnetization configuration and magnetization dynamics. A promising approach involves hybrid nanostructures combining ferromagnetic (FM) and superconducting (SC) nanoelements. It is possible to use SC nanoelements, which respond to a uniform external magnetic field by generating screening currents, to create magnetic field landscapes that strongly influence magnetization in nearby pristine FM layer.

We investigated spin-wave confinement induced in a uniform perpendicular magnetic anisotropy (PMA) layer by the stray field of an SC strip [1] placed above it. The SC strip produces an effective field well within the FM layer, capable of confining spin waves with frequencies lower than the ferromagnetic resonance frequency of the pristine FM layer [Fig. 1(c)]. The depth of this well and the number of bound states depend on the strength of the applied magnetic field.

Furthermore, we examined the possibility of creating a reconfigurable magnonic crystal in a pristine FM layer by applying a periodic sequence of SC strips [2]. The depth of the internal field modulation, and consequently the width of the magnonic band gaps, can be tuned by the applied uniform field.

Finally, we explored the use of the stray field of an SC nanoelement (ring) to stabilize a skyrmion in a uniform PMA layer in the absence of Dzyaloshinskii–Moriya interaction (DMI) [3]. We determined the range of SC ring sizes and FM material parameters for which such stabilization is possible.

Our studies demonstrate the feasibility of controlling magnetization textures and spin-wave dynamics locally by means of a uniform external magnetic field in hybrid FM–SC systems.

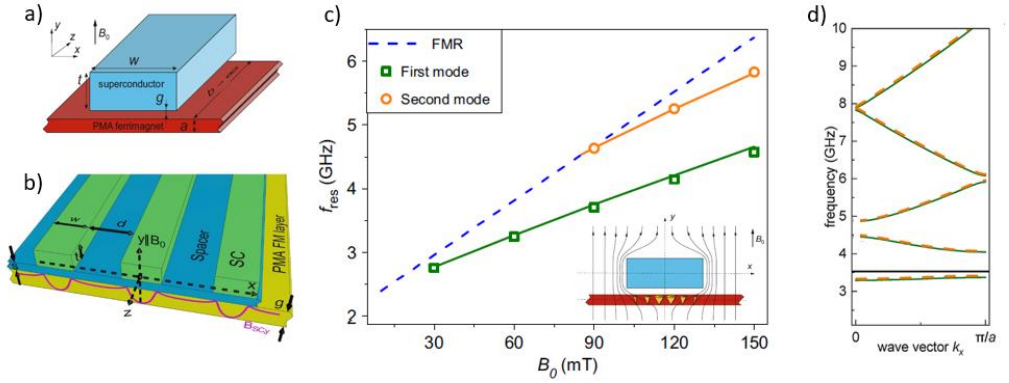

Fig. 1. A single superconducting strip (a) and a periodic sequence of superconducting strips (b) create a local well in the internal magnetic field [1] or a periodic field profile [2], which can confine (c) or scatter (d) spin waves.

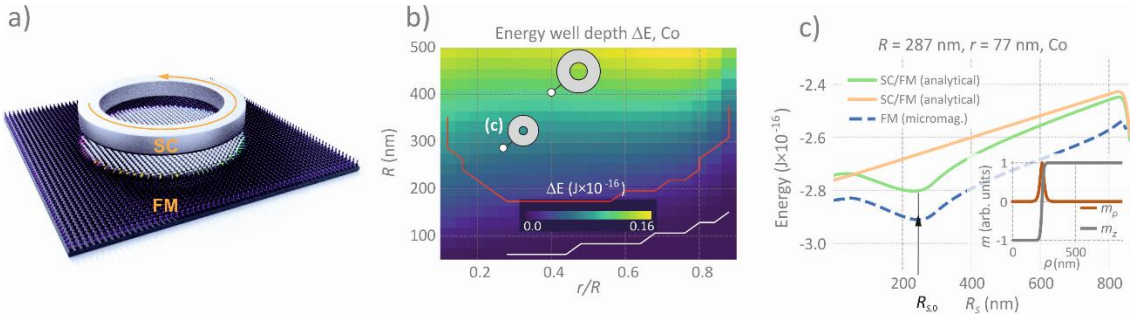

Fig. 2. A superconducting ring placed above an FM layer with PMA (a) can stabilize a skyrmion in the absence of DMI [3]. For appropriately chosen ring sizes (b), a skyrmion of a particular radius corresponds to an energy minimum of the magnetization texture.

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[2] J. Kharlan, K. Szulc, J.W. Kłos, G. Centała, Sci. Rep. **14**, 25594 (2024).
[3] J. Kharlan et al., arXiv:2505.07133 [cond-mat.mes-hall] (2025).