Book of abstracts

Spin wave localization in hybrid magnonic-superconducting naostructure

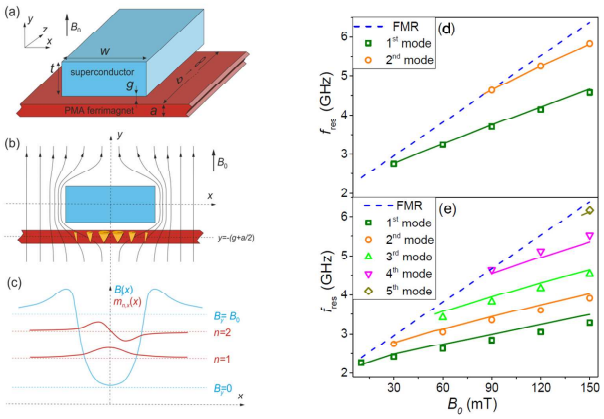
Julia Kharlan [1 2], Krzysztof Sobucki [1], Krzysztof Szulc [1], Sara Memarzadeh [1], Jaroslaw W. Klos [1]

[1] *Adam Mickiewicz University Poznan - Faculty of Physics, ISQI, Poland*

[2] *Institute of Magnetism NASU and MESU, Ukraine*

hybrid structure | localization | spin waves | superconductors |

The hybrid systems [1,2], where the superconductor and the ferromagnet are part of the same structure and interact with each other, usually offer much more flexibility both in design and implementation of new features that exotic materials which combines the ferromagnetic and superconducting properties [3]. One of the topics not fully explored is the problem of localization of spin waves in these systems. In this study, we conduct a theoretical and numerical investigation of the confinement of dipolar-exchange spin waves (SW), induced in a uniform (FM) ferrimagnetic layer by the stray field of a superconducting (SC) strip. The detailed description of these investigations is presented in our manuscript [4]. We considered hybrid system consisting of gallium-doped yttrium iron garnet (Ga:YIG) ferrimagnetic thin layer and Nb SC strip in Meissner state, separated by thin nonmagnetic spacer (Fig. 1(a)). The stray field of SC strip can be tuned by the external field and induce the well of static effective field of controllable depth in the FM layer. The well can confine the spin waves of the frequencies lower than the FMR frequency of FM layer in the absence of SC strip. Our semi-analytical and numerical studies were carried out in two stages. We first calculated the static stray field generated by the SC strip. It was determined from the distribution of superconducting currents, which was found by semi-analytical solution of the London equations using method developed in [5]. The static field generated by SC stripe was then included as a correction to the effective field to Landau-Lifshitz equation. We found that the number of spin wave bound states and their frequencies can be controlled by an external magnetic field. The dependence of frequencies of the localized SW modes on the external magnetic field is presented on the Fig. 1(b,c), for two SC strips differing in width. Also, we observe a larger number of localized SW modes for wider stripe, what is caused by two factors: (i) the frequency difference between SW modes energy levels becomes smaller due to the widening of the well (the main factor), and (ii) the depth of the well is slightly increased with the widening of SC strip.AcknowledgementsThe work was supported from the grants of the National Science Center – Poland, Nos. UMO2019/35/D/ST3/03729, UMO-2021/43/I/ST3/00550, UMO-2021/41/N/ST3/04478.



(a) A thin FM layer is exposed to the stray field of a rectangular SC strip. The layer and the strip are separated by a small gap. (b) The static internal magnetic field is lowered in the region of the FM layer underneath the SC strip. (c) This leads to the confinement of SW modes. (d,e) The dependence of the localized SW modes on the external magnetic field B0 for the system with stripes width w = 400 nm (d) and w = 800 nm (e). The solid lines and square dots correspond to the semi-analytical theory and micromagnetic simulations, respectively. Dashed lines shows FMR frequency of uniformly magnetized film.

References

I. F. Lyuksyutov et al., Adv. Phys. 54 (2005) 67
J. Linder et al., Nat. Phys. 11 (2015) 307
S. S. Saxena et al., Nature 406 (2000) 587
J. Kharlan et al., arXiv:2312.13029 (2023)
E. H. Brandt, Phys. Rev. B 54 (1996) 4246