Magnon-Fluxon Interaction in Coupled Superconductor/Ferromagnet Hybrid Periodic Structures

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Over the past decades the interest in coupled superconductor/ferromagnet (SC/FM) materials has continuously increased. Hybrid structure of this form are not only interesting from fundamental point of view but also provide promising prospects for information technology. One key idea is to use the stray field interaction between superconducting matter and ferromagnets to manipulate the propagation of spin waves in a magnonic wave guide. In this way a superconducting vortex lattice can act as a building block for a reconfigurable magnonic crystal with unique properties. Despite intensive research on this subject the fascinating nature of the coupled dynamics of SC/FM hybrids is not fully understood yet and only recently the first experimental evidence for magnon-fluxon-interaction has been found so far by Dobrovolskiy et al. (Nature Physics, 15, 477 (2019)).

Here we are aiming to obtain a deeper insight into the magnetization dynamics of a SC/FM bilayer by simulating such a structure under realistic conditions. To this end we solve the coupled time-dependent Ginzburg-Landau equations [1,2] for superconductivity and the Landau-Lifschitz-Gilbert equation for the magnetization dynamics. In accordance with the experiment we found that the presence of the vortices leads to the formation of a Bloch-like band structure in the magnonic spectrum. The width and position of these bands was observed to be highly susceptible to various system parameters like the FM layer thickness and width, structural imperfections in the vortex lattice, and on the strength of the vortex-field. In addition, we observed a tendency for magnon-confinement and band shifts towards lower frequencies of the low-energy modes above the location of individual vortices. In our simulations we found that the stray field of a periodic vortex lattice can be well approximated by an arrangement of air-separated ferromagnetic nano-cubes. Especially for large scale systems this approach substantially simplifies the task of solving the full system of coupled partial differential equations and paves the way for further research on the subject.

References:

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