Unconventional spin wave localization in magnonic nanostructures of long-range order

(in-depth report)

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Defects introduced into systems with long-range order, such as periodic or quasiperiodic lattices, can induce localized states of energies (frequencies) from usually forbidden gaps for propagating waves. This effect is also present in spin waves found in magnonic crystals or quasicrystals.

Identifying defects that involve rearrangement of building blocks in the crystals is comparatively easy. However, it is more difficult to systematically introduce defects into quasicrystals. Another challenge of studying defects in quasicrystals is the localization of bulk states that occurs even in the absence of defects. To analyze the impact of such defects, one possibility is to introduce so-called phonic defects, which are related to the perturbation of the structural degrees of freedom in quasicrystals - i.e. phasons.

Another unusual type of localization, counterintuitively observed despite the absence of defects in the crystal lattice, is associated with the existence of flat bands in the dispersion relation. This type of localized state, called compact localized states, is observed in bipartite lattices.

Firstly, we will discuss the conventional mechanism of spin-wave localization in magnonic crystals, which is related to the disruption of periodicity in these systems. Then we introduce the concept of phasonic defects in planar magnonic quasicrystal-perturbed Fibonacci sequences of flat stripes [1]. Subsequently, we present the compact localized states in a planar magnonic Lieb lattice [2].

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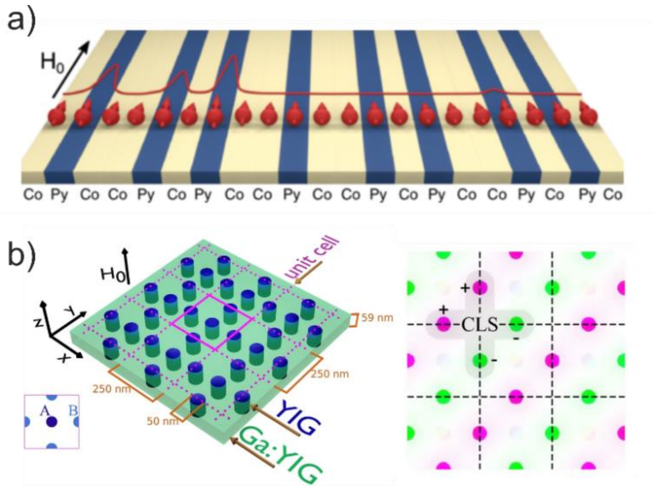

Fig. 1. The approximate of a Fibonacci quasicrystal resulting from the standard substitution rules. The structure is composed of Py and Co flat strips (30 nm thick and 300 nm wide), aligned side-by-side and being in direct contact. The field 0.1 T is applied along the strips. The sequence of tilted arrows and line in front of them visualizes the spin-wave mode profile. (b) Left: Magnonic Lieb lattice consists of YIG cylindrical nanoelements embedded within Ga:YIG matrix. The unit cell contains three inclusions of 50 nm. The separation between centers of inclusions is equal to 125 nm. Right: The profiles of the Bloch functions obtained for the basic Lieb lattice. The patterns characteristic for compact localized states (CLS) are presented at the point M for the second band. The CLS do not occupy minority sublattice A.

[1] S. Mieszczak, M. Krawczyk, J. W. Kłos, *Spin-wave localization on phasonic defects in a one-dimensional magnonic quasicrystal*, Phys. Rev. B **106**, 064430 (2022).
[2] G. Centała, J. W. Kłos, *Compact localized states in magnonic Lieb lattices*, Sci. Rep. 13, 12676 (2023).