Toward three-dimensional magnonic crystals

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Magnonic crystals (MCs) are materials with periodically modulated magnetic properties where the spin waves (SWs) band structure consists of intervals of allowed SW frequencies and forbidden gaps in which there are no allowed magnonic states.

In the recent past, most of the studies have been focused on planar nanostructures where the magnetic constituents have the same thickness, while, to the best of our knowledge, there are no reports of SW band structure in 3D MCs. This is mainly due to the difficulties associated with the fabrication of thickness modulated nano-elements by conventional nanofabrication techniques which require multilevel exposure process and alignment between successive fabrications steps.

Very recently, we proposed a new class of MCs constituted by closely packed thickness-modulated nanowires fabricated by the self-aligned shadow deposition technique. We have shown that this kind of structures support the propagation of collective SWs in the periodicity direction, thus demonstrated that layering along the third dimension is very effective for controlling the characteristics of the magnonic band.[1] More in details, a blue shift in frequency of the lowest frequency modes has been observed for thickness-modulated Permalloy (Py) NWs when compared to a reference planar array of Py NWs. Later, the investigation has been extended to the case of bi-layered Fe/Py NWs having either rectangular or L-shaped cross-section (upper layer of a half width with respect to the bottom one), for 10 nm thick Py layer and Fe thickness in the range between 0 and 20 nm.[2,3] Remarkably, it was found that the magnonic band structure was significantly altered by the combination of the two layers and by the thickness of the Fe layer.

Another possible approach to realize 3D MCs, is to have an array of ferromagnetic dots deposited on top of a continuous ferromagnetic film. We will present some preliminary results for this kind of structures and discuss the relevant aspects of the spin wave propagation.

[1] G. Gubbiotti et al., “Collective spin waves on a nanowire array with step-modulated thickness”, J. Phys. D Appl. Phys., 47, 105003 (2014)
[2] G. Gubbiotti et al., “Collective spin excitations in bi-component magnonic crystals consisting of bi-layer Permalloy/Fe nanowires” Phys. Rev. B 93, 184411 (2016)
[3] G. Gubbiotti et al., "Tailoring the spin waves band structure of one-dimensional magnonic crystals consisting of L-shaped iron/permalloy nanowires" J. Phys D: Appl. Phys. 50, 105002 (2017)