3D magnonics: controlling and visualizing spin waves with three-dimensional resolution

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Three-dimensional (3D) control of spin-wave dynamics represents a groundbreaking advancement in magnonics, enabling novel functionalities for nanoscale computing and signal processing [1]. In this context, this presentation highlights new approaches to control and image spin waves in 3D.

Two examples will be detailed: first, using magnetic X-ray laminography, we provided the first 3D imaging of propagating spin-wave modes within synthetic antiferromagnets (SAF) [2]. This technique captures with temporal and nanoscale resolution the 3D dynamics, the complex localization and interference of spin waves, revealing unexpected depth-dependent profiles originated from the interlayer dipolar interaction. These features can be tuned by controlling the composition and structure of the magnetic system.

Second, in Yttrium Iron Garnet (YIG) thin films, we demonstrate how a focused continuous-wave UV laser can promote a sharp increases of perpendicular magnetic anisotropy up to 30 times in a confined volume down to 100 nm in size, whose depth can be precisely tuned with the laser power [3]. This process stabilizes complex 3D spin textures throughout the film volume without significantly affecting its topography or crystalline structure. Regarding magnetization dynamics, the 3D nanopatterning produces substantial modulations of the spin-wave band structure and the emergence of novel non-reciprocal spin-wave modes, whose dispersion and spatial localization are tunable with the laser power. Furthermore, this approach enable the fabrication of single-step three-dimensional magnonic crystals. Together, these works open new possibilities for 3D devices with tailored magnetic properties and complex magnonic functionalities.

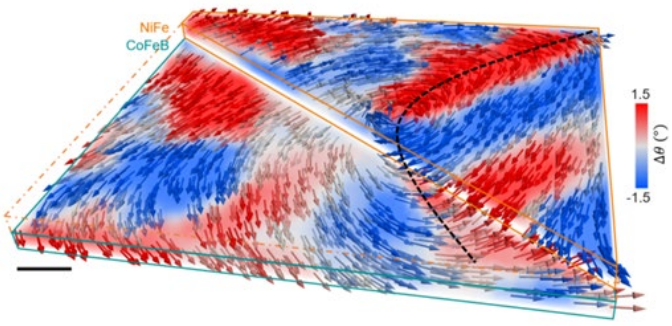

Figure 1. Experimental reconstruction of the three-dimensional magnetization dynamics (arrows) in SAF. The red-blue coloring is the in-plane component. The black dashed line indicates the presence of a domain wall. Scale bar, 200 nm.

References

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