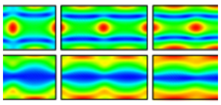

Measuring magnetic excitations in a magnonic crystal

In a ferromagnetic material, an excitation can produce a precessional movement of magnetic moments at frequencies in the range of 1 GHz or higher. This excitation can be triggered by light (Brillouin scattering), microwaves (ferromagnetic resonance), electric current (spin transfer) or acoustic waves. During precession, the magnetic moments can move in phase (wave vector k = 0) or with a certain phase shift (wave vector k ≠ 0). In the latter case, we speak of spin waves. Physicists have recently been interested in the propagation of spin waves in magnonic crystals (like photonic crystals but having a periodic magnetic configuration) for applications in the transport and processing of information.

Members of the team «Growth and properties of hybrid systems in thin layers» at the INSP carried out a complete study of the magnetization dynamics of a nitrogen-implanted iron thin film , which naturally has a periodic and highly ordered magnetic configuration, typical of magnonic crystals (FIG. 1). This study deals with the magnetic excitations of this periodic system as a function of the external magnetic field at k = 0. This study, based on Brillouin scattering measurements (in collaboration with the University of Perugia), broadband ferromagnetic resonance measurements (INSP) and micromagnetic simulations (Mumax3, INSP), has a two-fold interest: the spatial distribution of excited modes is studied in detail and the sensitivity of experimental techniques is discussed using selection rules. This last point, very general, allows us to better take advantage of the complementarity of the spectroscopic methods, to grasp the dynamics of magnonic crystals.

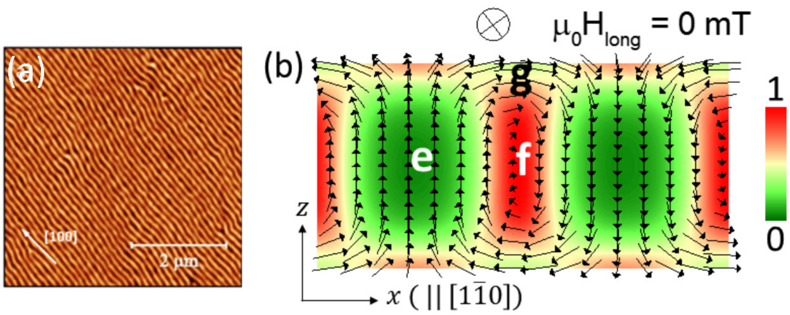

Figure 1
(a) MFM image taken at remanence after saturation along the [100] direction. The period of the stripes is of the order of 100 nm. (b) Side view of the stripe domains from the micromagnetic simulations (Mumax3). Regions of perpendicular magnetization (e), flux closure domains (g) and regions of in-plane magnetization (f, parallel to the stripes) can be distinguished.

Fe-N thin films have a perpendicular anisotropy which forces the magnetic moments to be oriented perpendicularly to the plane of the sample forming parallel stripes «up» and «down» (domains ‘e’ in Figure 1.b) separated by Bloch walls (domains ‘F’) and flux closure domains (domains ‘g’). Thanks to studies whose complementarity was shown, based on broadband ferromagnetic resonance and Brillouin scattering, we observed a first set of modes (n-PS) located at the surface of the stripe domains «up» and «down» and which are revealed by Brillouin scattering measurements (Figure 2). These modes progressively turn into stationary spin wave modes (Perpendicular Standing Spin Wave modes, PSSW) when the in-plane applied magnetic field is increased until saturation. Simulations using Mumax3 let us visualize the spatial distribution of these modes.
A second family of modes is visible only by ferromagnetic resonance with a microwave field parallel to the direction of the stripe domains. These modes are located inside the «up» and «down» domains where the local magnetization is perpendicular to the plane of the sample (domains ‘e’ in Figure 1.b) and disappear when the magnetization of the sample is saturated along the direction of the microwave field.

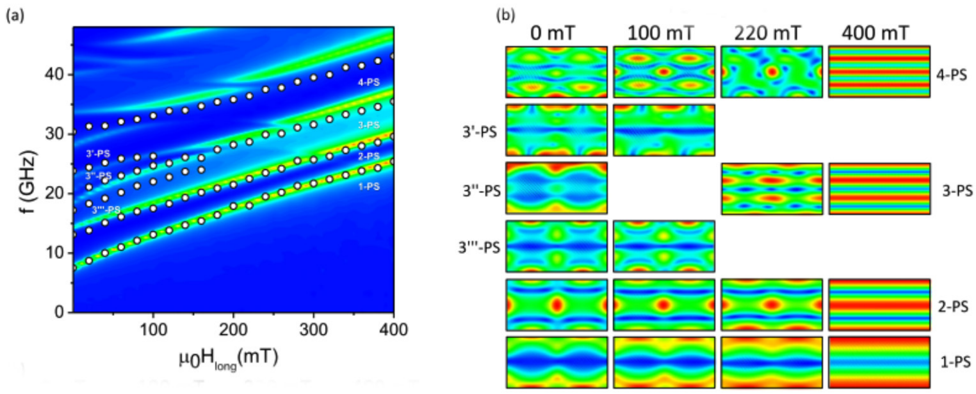

Figure 2
(a) Comparison between Brillouin measurements and micromagnetic simulations for a Hlong magnetic field parallel to magnetic stripe domains. (b) Spatial distribution of the dynamic magnetization module (Mumax3 simulations) showing the contributions of different magnetic domains to the main modes in a cross section of the sample. The areas in red contribute mainly. The modes at the surface are transformed when the magnetic field is increased.

hese studies done at $k = 0$ have an interest that goes beyond the Fe-N system because they will allow us to better understand the propagation of spin waves ($k \neq 0$) in stripe systems, such as FeGa, FePd, NiPd, and Co / Fe multilayers. The existence of periodic magnetic stripe domains should induce the appearance of forbidden frequency bands in the dispersion curves of spin waves, making this «self-organized» magnetic structuration interesting for magnonics.

Reference

"Magnetization dynamics of weak stripe domains in FeN thin films: a multi-technique complementary approach"
I. S. Camara, S. Tacchi, L.-C. Garnier, M. Eddrief, F. Fortuna, G. Carlotti, and M. Marangolo
Journal of Physics: Condensed Matter, 29, 465803 (2017)

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