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Antiferromagnetic textures imaged by probing thermally excited spin waves

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Imaging the magnetic state in antiferromagnets is a notoriously difficult task resulting from the compensation of the net magnetic moment in such materials. However, antiferromagnets are very promising systems for the development of advanced spintronics devices, owing to the robustness of their magnetic state and their fast dynamics, strengthening the need for efficient tabletop imaging techniques. Rather than focusing on the detection of the very weak stray fields produced by antiferromagnetic textures, we demonstrate here that the presence of localized objects can be revealed by probing the magnetic noise generated by thermally activated spin waves.

Because of the channeling of spin waves inside domain walls [1] or their scattering on objects like skyrmions, the resulting noise frequencies and amplitude are not spatially uniform. In order to access these variations with the appropriate nanoscale spatial resolution, we employ scanning NV center microscopy. NV centers are defects in the crystalline structure of diamond which behave like artificial atoms with a spin S=1 and can be used as quantum sensors, here integrated inside an atomic force microscope [2]. By monitoring the Zeeman shift of their magnetic resonance, we can record stray field maps with a high sensitivity, and by measuring their spin relaxation time T_1, we detect magnetic noise with a frequency component at the NV center resonance frequency, 2.87 GHz. We show that the acceleration of the NV center relaxation results in a drop of the emitted photoluminescence [3], allowing us to image the magnetic textures without the need to perform time-consuming measurements of T_1-maps.

The performances of this imaging technique are demonstrated on synthetic antiferromagnets hosting various non-collinear magnetic textures: domain walls, spirals and skyrmions [4], which we observe in simultaneously recorded stray field and photoluminescence maps [5]. Calculations of the spin waves dispersion relations inside the antiferromagnetic domains and the non-collinear textures indicate that our imaging contrast is resulting from the noise which originates from thermally activated spin waves. Nevertheless, additional measurements on skyrmion-hosting layers point out the presence of a significant magnetic disorder within the antiferromagnetic background, which underline the complexity of these synthetic antiferromagnetic stacks.

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[3] Rollo et al, Phys Rev B 103, 235418 (2021)
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