Investigating Phase Transitions in Van Der Waals Magnets using a Quantum Sensor

Debarghya Dutta, Clément Pellet-Mary, Patrick Siegwolf, Märta Tschudin, David Broadway, and Patrick Maletinsky

University of Basel

The advent of two-dimensional magnetic van der Waals(vdW) heterostructures has expanded the boundaries of nano-magnetism and led to novel ideas for information transfer in the field of spintronics[1]. By probing the intrinsic layer-dependent magnetic phases, it is possible to gain fundamental understanding of spin structure and dynamics[2]. We study these exotic magnetic phase transitions using a local, non-invasive scanning magnetometry technique. Our sensor consists of a single nitrogen-vacancy (NV) center in diamond that is attached to an AFM cantilever to enable scanning measurements at cryogenic temperatures[3].
In particular, we are studying the magnetic phases of CrSBr, a layered 2D vdW anti-ferromagnet with intralayer ferromagnetic (FM) and interlayer anti-ferromagnetic (AFM) coupling[4]. We quantitatively characterize the FM to AFM phase transition in bilayer CrSBr by directly imaging the FM-AFM phase boundary as it propagates through the sample[5]. Strikingly, we observe the formation of characteristic cusp-like features in the FM-AFM phase wall which leads to the creation and propagation of AFM-AFM domain walls. Furthermore, we correlate the interplay between the phase walls and neighboring connected CrSBr multilayers to ultimately decipher the spin configuration of the underlying layers.

[1] Chumak, A., Vasyuchka, V., Serga, A. et al. Magnon spintronics. Nature Phys 11, 453-461 (2015).
[2] Gibertini, M., Koperski, M., Morpurgo, A.F. et al. Nat. Nanotechnol. 14, 408-419 (2019).
[3] L. Thiel et al. Science 364, 973-976 (2019).
[4] S.A. López-Paz et al., Nat. Commun. 13, 4745 (2022).
[5] Tschudin, Märta A., et al. "Nanoscale magnetism and magnetic phase transitions in atomically thin CrSBr." arXiv preprint arXiv:2312.09279 (2023).