Nanoscale magnetic imaging with single electronic spins

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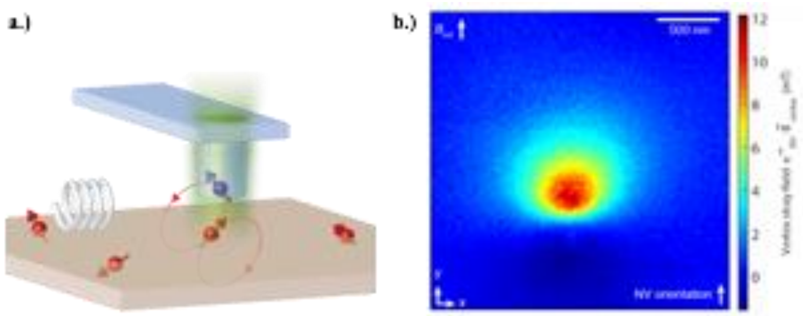
An isolated electronic spin can yield a close-to-ideal magnetometer to investigate magnetic phenomena on the nanoscale [1]. Spins are natural magnetometers by virtue of their Zeeman response to magnetic fields. Additionally, quantum coherence and control can be exploited to tailor their response towards excellent magnetic field sensitivities. Lastly, such spins can be localized to atomic length scales, which enables nanoscale resolution in imaging. The electronic spin of the Nitrogen-Vacancy center in diamond has been identified as a particularly fruitful system to implement these concepts [2]. It combines the above benefits with the ability of optical spin readout and initialization and operates from cryogenic temperatures to ambient conditions, all while maintaining exceptional quantum coherence properties. In the best case, this results in a non-invasive and quantitative magnetometer with single-spin sensitivity and nanoscale spatial resolution - a device with many highly promising applications in science and technology.



a.) Schematic of single spin based quantum sensing: A diamond scanning probe (blue) contains a single nitrogen vacancy (NV) spin and is used for nanoscale magnetic imaging. b.) Stray magnetic field of an isolated vortex in the high-temperature superconductor $YBa_2Cu_3O_7$, imaged by scanning NV magnetometry at 4 K. The quantitative image yields a ~10 nm spatial resolution and was obtained at a magnetic field sensitivity ~1 μT/$Hz^{0.5}$.

In my talk I will present recent activities of the quantum sensing group at the University of Basel in nanoscale NV magnetometry of condensed-matter systems. Specifically, I will describe our experimental approach to realizing such quantum magnetometers and discuss two systems we currently investigate using this technique. I will discuss an experiment where we employ scanning NV magnetometry to image individual vortices in the high-temperature superconductor YBa_2Cu_3O, [3] and some more recent findings, where we were able to image and study domains in the magnetoelectric antiferromagnet Cr_2O_3. In both cases, NV magnetometry allowed us to quantitatively determine essential system parameters of the materials under study - the London penetration depth for YBCO and the surface magnetic moment density for Cr_2O_3. Both are central quantities for the understanding of the respective materials, and both have been notoriously hard or impossible to determine using previously existing experimental approaches. Our results therefore illustrate the power of NV magnetometry in exploring local magnetic properties of electronic systems with nanoscale resolution and the promise our technology holds for future exploration of complex, condensed matter systems.

[1] Chernobrod, B. *et al.*, J. Appl. Phys. 97, 01490
[2] Taylor J. *et al.*, Nature Phys. 4, 810, Maletinsky P., *et al.*, Nat. Nanotechnology 7, 320
[3] Thiel L. *et al.*, Nature Nanotechnology, 10.1038/nnano.2016.63