

Exploring Condensed Matter Physics with a Quantum Spin Microscope

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Understanding spatially inhomogeneous magnetic states and their dynamics is an important challenge in the study of quantum magnets and correlated quantum materials. A wide range of techniques have been developed for imaging local magnetic fields (magnetization), including Lorentz microscopy, magneto-optical Kerr microscopy, magnetic force microscopy (MFM), scanning SQUID microscopy, and so on. Each technique has its own strengths and limitations in spatial resolution, sensitivity, accessible environments, and quantitative interpretation. Thus, the development and application of local magnetic field measurement techniques remain attractive challenges for experimental researchers.

Recently, there has been growing interest in probing material properties using nitrogen-vacancy (NV) centers in diamond as quantum magnetic field sensors. NV centers possess unique internal energy levels, and their spin states can be optically read out via optically detected magnetic resonance (ODMR). Because the ODMR spectrum of NV centers exhibits Zeeman splitting in a magnetic field, analyzing the spectrum enables high-precision measurements of the local magnetic fields experienced by the NV centers.

We are developing a “quantum spin microscope,” namely a microscope based on diamond quantum sensors, to quantitatively evaluate and visualize the magnetic properties of various materials. In this presentation, we will introduce our recent efforts in quantum spin microscopy, including quantitative imaging of magnetic phase transitions and fluctuations in few-layer CrI₃ [1] and observation of chiral magnetic domain walls in the antiferromagnet Mn₃Sn [2]. We will also discuss recent extensions of quantum spin microscopy to extreme environments, including magnetic-field imaging under very high pressure [3].

[1] H. Gu *et al.* (in preparation).

[2] M. Tsukamoto *et al.*, *Observation of chiral domain walls in an octupole-ordered antiferromagnet*, Phys. Rev. B **112**, L020404 (2025) [Editors’ Suggestion].

[3] K. Yamamoto *et al.*, *High-pressure magnetic transition in iron observed via diamond quantum sensing*, High Pressure Research, 1-14 (2026).