Quantum microscopy with van der Waals heterostructures

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Quantum microscopes based on solid-state spin quantum sensors have emerged as powerful tools for probing material properties and physical processes in regimes not accessible to classical sensors, especially on the nanoscale [1,2]. However, to date these microscopes have relied on quantum defects hosted in a rigid, three-dimensional crystal (typically diamond), limiting their ability to closely interface with the sample. Here we demonstrate a versatile and robust quantum microscope using quantum defects embedded within a thin layer of a van der Waals (vdW) material, hexagonal boron nitride (hBN). The spin defect is the negatively charged boron vacancy centre ($V_{\rm B}^-$), a recently discovered spin-1 system that exhibits a robust optically detected magnetic resonance (ODMR) response over a wide range of temperatures up to 600 K [3,4]. To showcase the multi-modal capabilities of our quantum microscopy platform, we assemble several vdW heterostructures incorporating a quantum-active hBN layer. We demonstrate time-resolved, simultaneous temperature and magnetic imaging near the Curie temperature of a vdW ferromagnet, as well as map out charge currents and Joule heating in an operating graphene device [5]. By enabling atomic-scale proximity and seamless integration with the sample, the hBN quantum sensor represents a paradigm shift for nanoscale quantum sensing and microscopy.

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[5] A. J. Healey et al, *Preprint arXiv:2112.03488* (2021).