A robust scanning diamond sensor for nanoscale imaging with single nitrogen-vacancy centres

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The nitrogen-vacancy defect centre in diamond has potential applications in nanoscale electric and magnetic-field sensing, single-photon microscopy, quantum information processing and bioimaging. These applications rely on the ability to position a single nitrogen-vacancy centre within a few nanometres of a sample, and then scan it across the sample surface, while preserving the centre's spin coherence and readout fidelity. However, existing scanning techniques, which use a single diamond nanocrystal grafted onto the tip of a scanning probe microscope, suffer from short spin coherence times due to poor crystal quality, and from inefficient far-field collection of the fluorescence from the nitrogen-vacancy centre. Here, we demonstrate a robust method for scanning a single nitrogen-vacancy centre within tens of nanometres from a sample surface that addresses both of these concerns. This is achieved by positioning a single nitrogen-vacancy centre at the end of a high-purity diamond nanopillar, which we use as the tip of an atomic force microscope. Our approach ensures long nitrogen-vacancy spin coherence times (75 ţs), enhanced nitrogen-vacancy collection efficiencies due to waveguiding, and mechanical robustness of the device (several weeks of scanning time). We are able to image magnetic domains with widths of 25 nm, and demonstrate a magnetic field sensitivity of 56 nT Hz–1/2 at a frequency of 33 kHz, which is unprecedented for scanning nitrogen-vacancy centres.
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