Diamond Parabolic Reflectors for Nanoscale Quantum Sensing

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The development of quantum sensing and nanoscale magnetometry using the Nitrogen-Vacancy (NV) center in diamond has opened up a plethora of sensing possibilities [1, 2]. These atomic-scale defects make use of a single electron spin, stable from room temperature to cryogenic conditions, which makes the NV center an ideal system for investigating sensitive, nanoscale, magnetic systems. However, as with most solid-state, atomic defects, the high index of refraction of the diamond makes extracting NV fluorescence a challenge. Furthermore, for many quantum sensing applications, the sensitivity is limited by the separation between the NV and sample, and in scanning magnetometry, this also defines the resolution. These requirements call for novel device architectures that enable sensing with shallow NV centers, while still allowing for the efficient extraction of the emitted NV fluorescence for spin readout.

We address both of these aspects by fabricating all-diamond parabolic reflectors, which we employ as scanning probes for nanoscale magnetometry with unprecedented performance. We turn the high index of refraction of diamond into an advantage and realise waveguides, which redirect up to 80\% of the emitted NV fluorescence into a single, collimated mode [1]. The parabolic design with a truncated apex is furthermore designed such that the shallow, implanted NV’s sit at the focus of the parabola for optimal collection efficiency while achieving a tip-to-sample spacing of 40-50 nm during scanning.

In this talk, we present the fabrication techniques used to create these parabolic reflectors, and establish the performance of the scanning tips through magnetometry on antiferromagnetic Cr\textsubscript{2}O\textsubscript{3}. We image antiferromagnetic domains in thin film Cr\textsubscript{2}O\textsubscript{3} [2], as well as the stray fields of stripes patterned into monodomain, single-crystal Cr\textsubscript{2}O\textsubscript{3}.