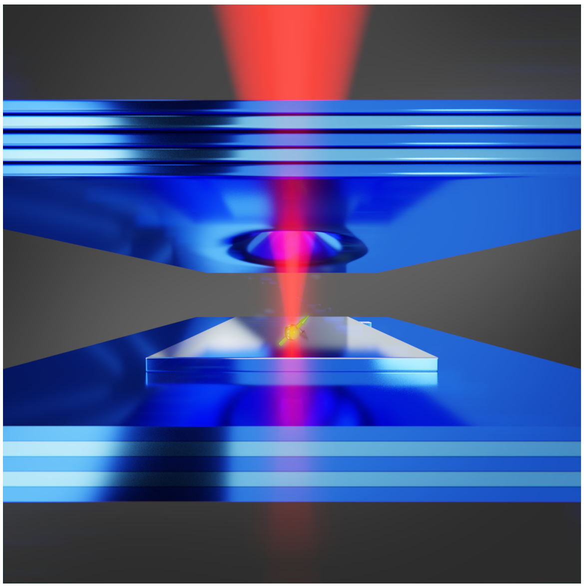

Engineering of the photonic environment of single NV centers in diamond

The nitrogen-vacancy (NV) center in diamond has an optically addressable, highly coherent spin. However, an NV center even in high quality single-crystalline material is a very poor source of single photons: extraction out of the high-index diamond is inefficient, the emission of coherent photons represents just a few per cent of the total emission, and the decay time is large. In principle, all three problems can be addressed with a resonant microcavity, which significantly boosts the emission rate of coherent photons into the cavity mode based on the Purcell effect. In practice though, it has proved difficult to implement this concept: photonic engineering hinges on nano-fabrication yet it is notoriously difficult to process diamond without degrading the NV centers.

In this thesis, we present a microcavity scheme which employs minimally processed diamond membranes, thereby preserving the high quality of the starting material. The miniaturized plano-concave Fabry-Pérot microcavity platform features full *in situ* spatial and spectral tunability. We demonstrate a clear change in the lifetime for multiple individual NV centers on tuning both the cavity frequency and anti-node position. The overall Purcell factor for the zero-phonon line (ZPL) of $F_{\mathrm{P}}^{\mathrm{ZPL}} \sim 30$ translates to an increase in the ZPL emission probability from $\sim 3\,\%$ to $\sim 46\,\%$.

Furthermore, we report the creation of a low-loss, broadband optical antenna giving highly directed output from a coherent single spin in the solid state. The device, the first crystalline solid-state realization of a dielectric antenna, is engineered for individual NV electronic spins in diamond. The photonic structure preserves the high spin coherence of single-crystalline diamond ($T_2 \gtrsim 100\,\mu$s). We demonstrate a directionality of close to 10 and single photon count rates approaching one MHz. The analysis of the angular emission pattern of our device suggests that 95 % of the broadband NV fluorescence is channeled into a solid angle corresponding to a numerical aperture of 0.8.

The abovementioned approaches feature complementary benefits. The narrowband enhancement of the ZPL emission rate provided by the microcavity benefits applications in quantum information processing relying on coherent photons. With the prospect of integrating lifetime-limited emitters and achieving a high ZPL collection efficiency our results pave the way for much enhanced spin-photon and spin-spin entanglement rates. On the other hand, by channeling the major fraction of the broadband NV fluorescence into a narrow solid angle the dielectric optical antenna facilitates efficient spin readout. Our approach enables a near-unity collection efficiency which, upon mitigation of the known photon losses, renders it a potential key technology for quantum sensing applications.

List of publications

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