Cavity QED with diamond nitrogen-vacancy centers formed by carbon implantation

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A negatively charged nitrogen-vacancy (NV) center in diamond coupled to an open Fabry-Perot microcavity is a promising spin-photon interface [1-4]. Implementation of diamond into the microcavity requires thinning it down to ~µm thickness while maintaining the NV optical coherence, a well-known challenge with standard NV creation methods. Recent studies have shown that the commonly used method, nitrogen implantation followed by annealing, results in NV centers with reduced optical coherence (linewidths above 1 GHz, 90 times the Fourier transform limit) compared to the optical coherence of NVs formed from native nitrogen [5-6]. We present an improved NV creation protocol in which we implant carbon ions instead of nitrogen ions once all diamond microstructuring has been completed. We show excellent NV optical coherence even in membranes thinner than 2 µm, with over 50% of the emitters showing optical linewidths below 150 MHz (Fig. 1). These membranes are then embedded in an open microcavity. Characterization of the cavity at cryogenic temperatures shows Q-factors up to 127 000, corresponding to a finesse of 7900 (Fig. 2). We argue that coupling the emission of a single NV center in the membrane to a cavity mode should result in a Purcell enhancement of up to 50. This would increase the success probability of remote spin-spin entanglement by more than two orders of magnitude, facilitating the scaling-up of distributed quantum networks based on spins in diamond.

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Figures

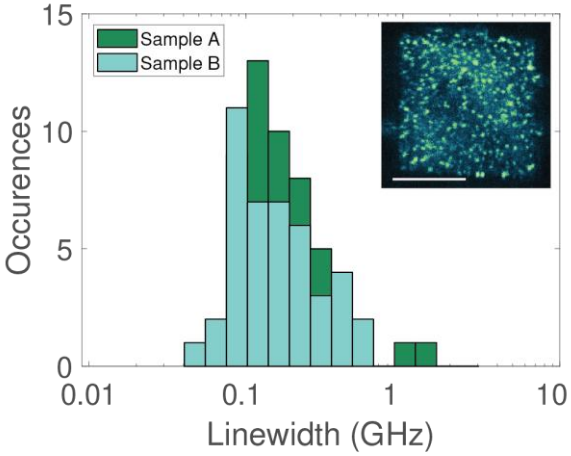

Figure 1: Linewidth distributions measured in 1.96-4.86 µm thick microstructures. Inset: confocal scan of the NV centers in one of the microstructures. (Scalebar: 10 µm)

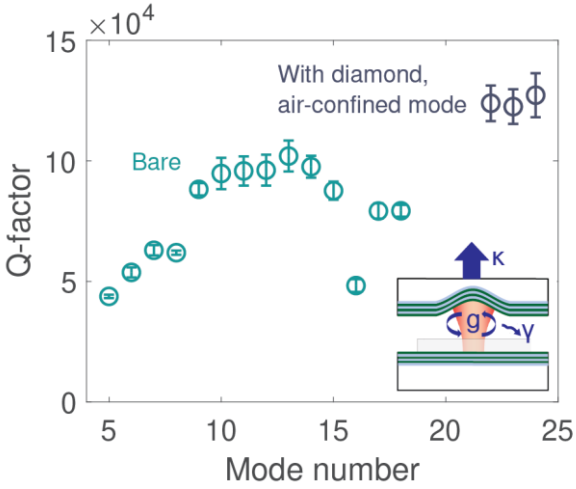

Figure 2: Q-factors of the microcavity at 4 K as a function of mode number.