Resonance Fluorescence from a Single Diamond Nitrogen-Vacancy Center in the Purcell Regime

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The negatively-charged nitrogen-vacancy center (NV) in diamond combines spin-dependent optical transitions and an inherent electro-nuclear multi-spin register with coherence time $> 1\,\mathrm{s}$ [6], enabling the entanglement of stationary and propagating photonic qubits. These features enabled pioneering experiments, culminating in the development of a 3-node quantum network [1, 7, 2]. However, the $\sim 3\%$ fraction of coherent zero-phonon line (ZPL) to phonon sideband (PSB) emission severely limits entanglement rates, and mitigation attempts using nanophotonic cavities resulted in catastrophic linewidth broadening, precluding spin-photon entanglement generation.

An alternative approach, relying on the integration of a minimally-processed diamond membrane into an open microcavity, has so far been hindered by residual charge noise, poor out-coupling efficiencies, negligible Purcell enhancement, or a combination of these factors [4, 5].

We tackle this decade-old challenge by interfacing a low-charge-noise NV, fabricated following an improved method [3], with a high-finesse, single-sided open microcavity at 4.7 K (see Fig. 1). The coupling g_{ZPL} between the optical mode and the NV leads to a measured ZPL fraction enhanced by over an order of magnitude to 44% . This enhancement is key to measuring for the first time NV resonance fluorescence (RF) – without relying on any temporal filtering – a stepping stone toward spin-photon entanglement. The recorded RF rates, up to 86 kcts/s, surpass significantly state-of-the-art rates using solid-immersion lenses. In addition to the cycling transition usually used for spin-photon entanglement, we also show that spin-flipping transitions can be addressed, opening the way for efficient, high-fidelity resonant spin initialization in the cavity. Combined with the observation of coherent optical driving dynamics, these results establish our platform as an efficient photonic interface for quantum applications.

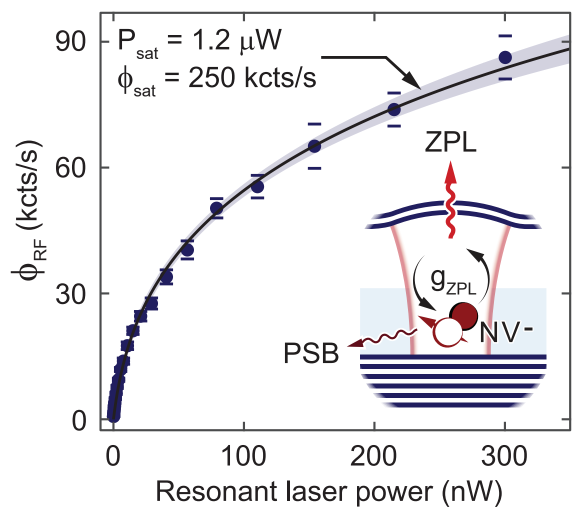

Fig. 1. RF photon flux ϕ_{RF} as a function of resonant driving power. A model (solid curve) taking into account coherent driving and charge noise closely reproduces the data and reveal a fully saturated flux ϕ_{sat} of 250 kcts/s. Inset: one-sided microcavity coupled to an NV with strength g_{ZPL}. The cavity enhances and funnels the ZPL fraction of the spectrum.

References

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