Citation (APA)
Rodriguez, D. B., Codreanu, N., Turan, T., Waas, C., Beukers, H. K. C., Pasini, M., Wienhoven, L. G. C., Breevord, J. M., & Hanson, R. (2025). SnV centers in photonic crystal cavities as a platform for quantum network nodes. In *Quantum 2.0 in Proceedings Optica Quantum 2.0 Conference and Exhibition* Article QM3A.5 (Quantum 2.0 in Proceedings Optica Quantum 2.0 Conference and Exhibition). Optical Society of America (OSA).

Optica Quantum 2.0 Conference 2025 © Optica Publishing Group
2025

SnV centers in photonic crystal cavities as a platform for quantum network nodes

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Abstract: Diamond photonic crystal cavity parameters are measured at cryogenic temperatures. In-situ resonance frequency tuning through gas desorption allows us to probe the SnV-cavity system. © 2025 The Author(s)

1. Introduction

Solid-state spins with optical interfaces are a promising route towards realizing scalable, long-distance quantum network communication nodes [1]. In particular, tin-vacancy centers (SnV) in diamond have risen as a compelling choice due to their comparably high spontaneous-emission efficiency into the zero-phonon line (ZPL) and suitability for photonic integration [2]. Additionally, integration into photonic crystal cavities further enhances the ZPL emission rate and provides alternative routes towards spin-spin entanglement [3]. Here, we report on our latest progress towards coupling SnVs to photonic crystal cavities.

2. Results

Diamond photonic crystal cavities are designed and then fabricated based on the quasi-isotropic etch undercut method [2]. Due to fabrication uncertainties, a scaling parameter is swept that applies to all cavity geometrical dimensions except its thickness. As a result, we obtain sets of nanophotonic cavities with distinct mean resonance wavelengths. This allows us to select the cavities that are closest to our desired wavelength. In Figure 1, an exemplary set of fabricated cavities is shown. To measure the resonance of the cavity, a pulsed white-light laser is used. The light is sent via a tapered optical fiber, fabricated using an HF wet-etch method [4]. The reflection from the device is sent to a spectrometer. We target a photonic crystal cavity with a scaling of 98%, initially characterized to be at $\sim$ 612nm. We let a small leak rate of nitrogen gas into the cryostat chamber, which deposits on the cold devices and red-shifts the resonance frequency. We do this until the latter is past the 619nm ZPL of SnV centers. Afterwards, we shine a continuous-wave (CW) 515nm laser to controllably blue-shift the cavity back, via gas desorption, while tracking both the cavity resonance and the SnV photoluminescence (PL) of the devices. The PL is shown in Figure 2, where an initially dim SnV line lights up as it enters in resonance with the cavity. The intensity of the light emitted by the SnV into the cavity mode is expected to be proportional to

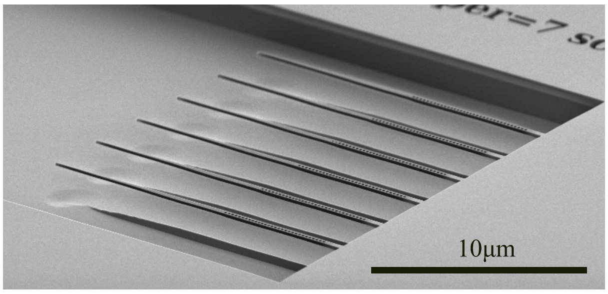

Fig. 1. **Fabricated photonic crystal cavities in diamond.** Scanning electron microscope image illustrating typical single-sided photonic crystal cavities. The strength of the coupling mirror is swept by varying its amount of holes. The nanobeams are terminated in a waveguide taper to couple to them efficiently with tapered optical fibers.

$1/(1+(2\Delta/\kappa)^2)$, with Δ the cavity-emitter detuning and κ the cavity energy decay rate [5]. The left side of Figure 2 shows a lorentzian fit of the SnV line trace.

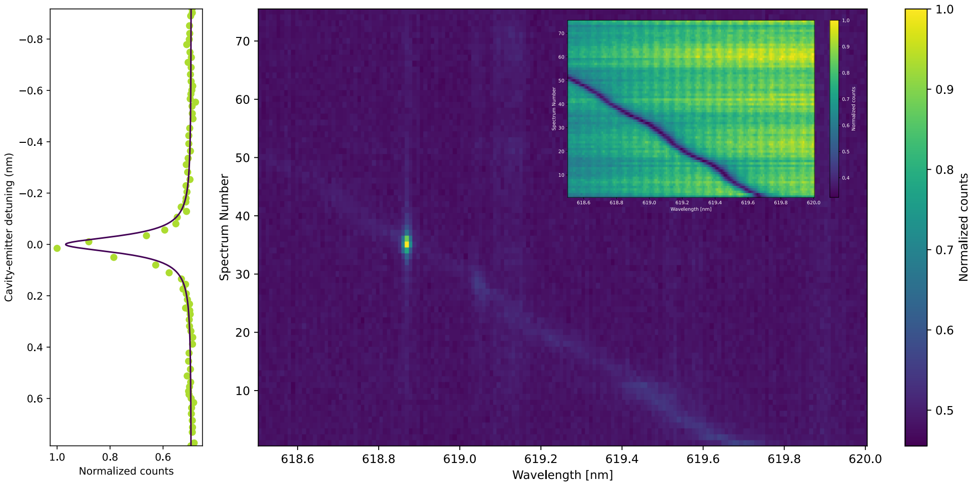

Fig. 2. **Cavity tuning and increase in the collection of SnV-emitted light.** Sequential PL measurements under ~ 2mW of continuous-wave 515nm excitation. Left: trace of the PL counts at 618.87nm, where the dots are the experimental data and the solid line is a lorentzian fit. Inset: sequential PL measurements under pulsed white-light laser excitation, explicitly tracking the cavity resonance. The light is collected in reflection, giving rise to a dip at the resonance frequency. The green and white PLs are interleaved one after the other. The average quality factor measured while tuning this device is $Q \sim 8.8 \cdot 10^3$.

3. Acknowledgments

We acknowledge support from the joint research program "Modular quantum computers" by Fujitsu Limited and Delft University of Technology, co-funded by the Netherlands Enterprise Agency under project number PPS2007, from the Dutch Research Council (NWO) through the Spinoza prize 2019 (project number SPI 63-264), from the Dutch Ministry of Economic Affairs and Climate Policy (EZK) as part of the Quantum Delta NL program, from the Quantum Internet Alliance through the Horizon Europe program (grant agreement No. 101080128), from the European Union's Horizon Europe research and innovation program under grant agreement No. 101102140 – QIA Phase 1.

References

1. D. D. Awschalom, R. Hanson, J. Wrachtrup, and B. B. Zhou, "Quantum technologies with optically interfaced solid-state spins," Nat. Photonics **12**, 516–527 (2018).
2. M. Pasini, N. Codreanu, T. Turan, A. Riera Moral, C. F. Primavera, L. De Santis, H. K. C. Beukers, J. M. Brevoord, C. Waas, J. Borregaard, and R. Hanson, "Nonlinear quantum photonics with a tin-vacancy center coupled to a one-dimensional diamond waveguide," Phys. Rev. Lett. **133**, 023603 (2024).
3. C. M. Knaut, A. Suleymanzade, Y.-C. Wei, D. R. Assumpcao, P.-J. Stas, Y. Q. Huan, B. Machielse, E. N. Knall, M. Sutula, G. Baranes, N. Sinclair, C. De-Eknamkul, D. S. Levonian, M. K. Bhaskar, H. Park, M. Lončar, and M. D. Lukin, "Entanglement of nanophotonic quantum memory nodes in a telecom network," Nature **629**, 573–578 (2024).
4. M. J. Burek, C. Meuwly, R. E. Evans, M. K. Bhaskar, A. Sipahigil, S. Meesala, B. Machielse, D. D. Sukachev, C. T. Nguyen, J. L. Pacheco, E. Bielejec, M. D. Lukin, and M. Lončar, "Fiber-coupled diamond quantum nanophotonic interface," Phys. Rev. Appl. **8**, 024026 (2017).
5. T. G. Tiecke, J. D. Thompson, N. P. de Leon, L. R. Liu, V. Vuletić, and M. D. Lukin, "Nanophotonic quantum phase switch with a single atom," Nature **508**, 241–244 (2014).