Strain control of silicon-vacancy centers in diamond nanophotonic devices

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Abstract: We present a nano-electromechanical platform for controlling optical transitions from spatially separated color centers in diamond waveguides. We use this technology to greatly suppress spectral diffusion and demonstrate entanglement between separate emitters.

1. Introduction

Silicon-vacancy (SiV) color centers in diamond have excellent optical and spin coherence properties, making them ideal candidates for integration into quantum networks [1]. However, their applications are limited by their spectral inhomogeneity and diffusion when implanted within nanophotonic devices. We present a platform for nano-electromechanically tuning and stabilizing SiV spectral lines inside nanophotonic structures with emitter tuning range 3 times larger than the SiV inhomogeneous distribution. We tune two, waveguide coupled SiV color centers into resonance using strain and generate an entangled superradiant state between them. We demonstrate that this technique can be used for broad bandwidth suppression of spectral diffusion and to drive spectral lines with tens of MHz bandwidth. Our platform for cavity coupled, individually tunable solid state quantum emitters should allow for optically mediated entanglement between emitters and is a step towards the creation of a quantum repeater network.

2. Experimental Configuration

Our diamond waveguide device is created by angled ion beam etching [2] followed by the creation of silicon vacancy centers using masked implantation. Strain is applied in the diamond beams by applying voltage to metal electrodes on the device and the substrate. (Figure 1a) This deflects the diamond beam, which in turn, strains the SiV centers located in the proximity of the deflected region. The remarkable strain sensitivity of SiV centers allows us to tune their spectral lines by more than 160 picometers (Figure 1b), several times greater than inhomogeneous distribution of SiV centers observed in our nanophotonic devices (Figure 1b, shaded regions). We use two separate lasers to excite two spatially separated SiV centers inside the diamond waveguide and collect their emission through a tapered optical fiber in contact with the tapered end of the diamond waveguide (Figure 1c) [3]. The collected emission is filtered from laser excitation using a high finesse Fabry-Perot cavity filter and Hanbury-Brown-Twiss (HBT) experiment is performed on the filtered photons using a beamsplitter and two avalanche photodiodes.

3. Results

SiV centers exhibit significant amount of spectral diffusion in nanophotonic devices (Figure 2a) impeding their application in quantum experiments relying on optically mediated entanglement between two emitters. We demonstrate that the presented spectral tuning platform can rapidly lock the SiV spectral line to the desired frequency. This allows the suppression of the effects of spectral diffusion by an order of magnitude on several hours timescale (Figure 2b).

Full control of SiV spectral properties further enables entanglement demonstration between them. We use strain to tune two emitters on resonance (Figure 1b, line crossing) making their emission indistinguishable. The detection of a photon emitted by this system using an HBT configuration, conditionally creates an entangled superradiant state between the two SiV centers. We confirm the signature of the created entanglement by observing a peak in their photon correlation function at zero time delay.

This highlights the strain tuning platform as a promising path towards application of diamond solid state emitters in quantum network protocols.

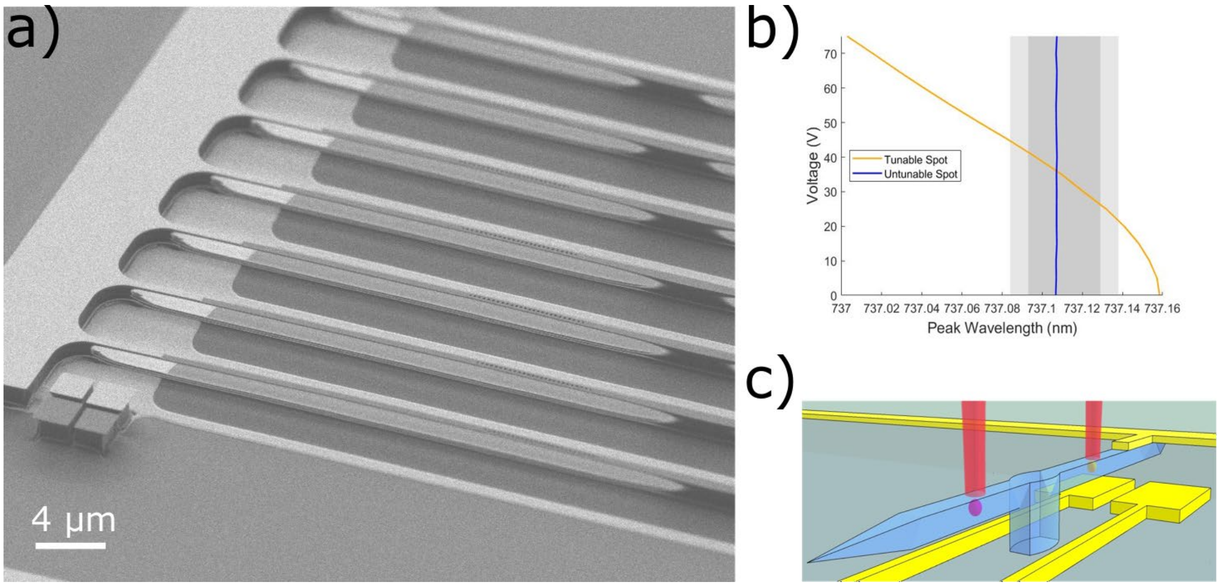

Figure 1: a) Scanning electron micrograph of the diamond waveguide device with deposited gold electrodes. b) Crossing of two emitter spectral lines. Applied voltage tunes the SiV in the deflected waveguide without perturbing the one outside it. c) Cartoon of the experimental configuration. Separate lasers excite two distant SiV centers within single device.

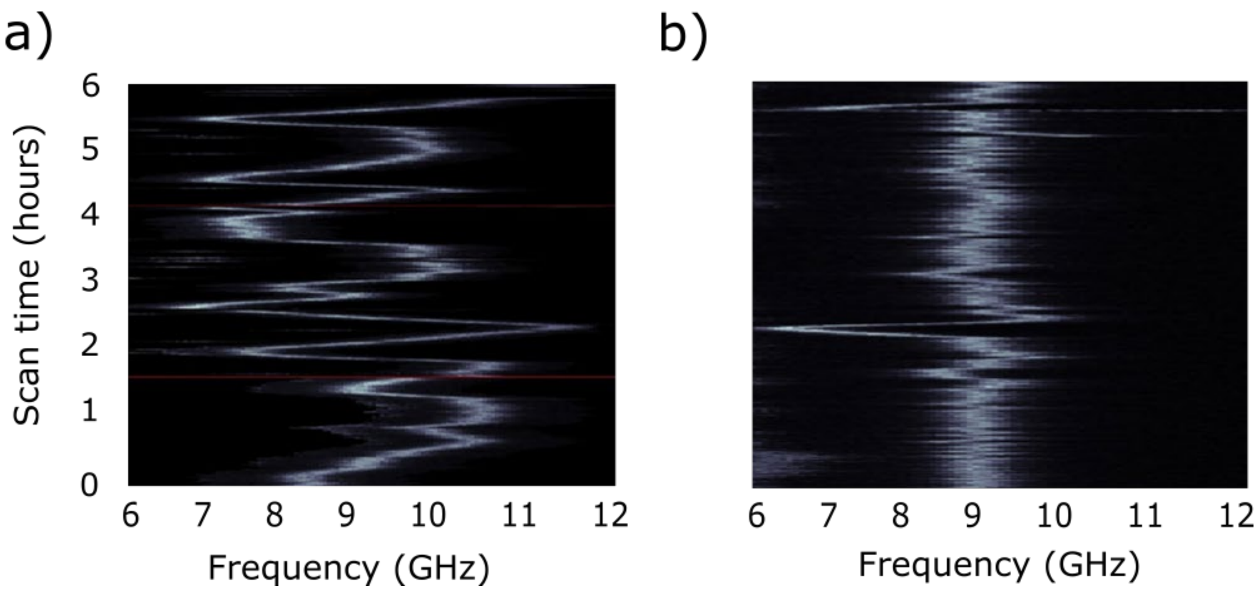

Figure 2: a) SiV spectral line position monitored over several hours. We observe significant amount of spectral instability. b) Stabilization of the SiV spectral line position using strain control.

4. References

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