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Quantum interference between photons from two waveguide-integrated tin-vacancy centers

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Abstract: Quantum networks are based on shared remote entanglement between local nodes by exchanging indistinguishable photons. We show Two-Photon Quantum Interference between tin-vacancy centers in diamond-waveguides and report on the progress towards remote entanglement generation.

1. Summary

1.1. Introduction

Quantum networks require interfaces capable of generating entanglement between a stationary qubit and flying photons [1], enabling distributed quantum computing and thereby bypassing the scalability bottlenecks of monolithic quantum processors [2]. The three main requirements are an efficient optical interface, high-fidelity control and long coherence time of the local qubit, as well as local ancilla qubits serving as a quantum memory.

Spin-photon interfaces in solid-state materials are one of the most promising systems, with the nitrogen-vacancy center (NV) in diamond particularly standing out with the demonstration of a multi-node network including quantum teleportation [3]. However, the intrinsically low emission probability of indistinguishable photons (small Debye-Waller factor) and spectral instability in structured photonic environments limit its scalability.

Tin-vacancy centers in diamond have emerged as an alternative with advantages like a large Debye-Waller factor and compatibility with photonic nanostructuring [4]. Operation at liquid helium temperatures and an efficient microwave ground-state control [5, 6] have recently been shown, as well as first steps toward a nuclear quantum memory [7]. To probe the full potential for quantum networks, benchmarking the single-photon indistinguishability by quantum interference measurements is necessary. So far, this has been shown for consecutive photons from a single emitter [8] as well as for photons from two emitters in bulk samples [9]. Here, we show two-photon quantum interference measurements from two separate emitters integrated into nano-structured waveguides.

1.2. Device

Tin-vacancy centers are efficiently coupled out of nanofabricated diamond waveguides via a lensed fiber configuration (Fig. 1 (a)) [10], allowing countrates in excess of 200 kcps. Implantation-induced strain enables efficient microwave driving with Rabi frequencies of more than 2 MHz via wire bonded wires. Emitters with close resonance frequencies in separate waveguides can be found despite local strain variations.

1.3. Two-Photon Quantum Interference

We use two emitters with the same crystallographic orientation with a frequency difference of 4.17 ± 0.1 GHz. The spectral overlap is achieved by tuning the spin-conserving transition frequency via a static magnetic field. Fast pulses with a temporal width of 1.5 ns are generated via an amplitude electro-optic modulators and enable a single-photon detection probability of more than 2e−4 counts-per-shot after charge-resonance checking. Fig. 1 (b) shows the measured coincidence events for a train of single-photons from the two emitters in a Hong-Ou-Mandel (HOM) measurement. The absence of counts at the central time-bin signifies two-photon quantum interference. Correcting for noise counts, we extract a photon indistinguishability of $\eta = 0.68 \pm 0.07$.

1.4. Discussion and Outlook

With the measured two-photon quantum interference in a nanostructure, all the individual components of a spin-photon interface have been demonstrated. The indistinguishability value will need improvement and is subject to

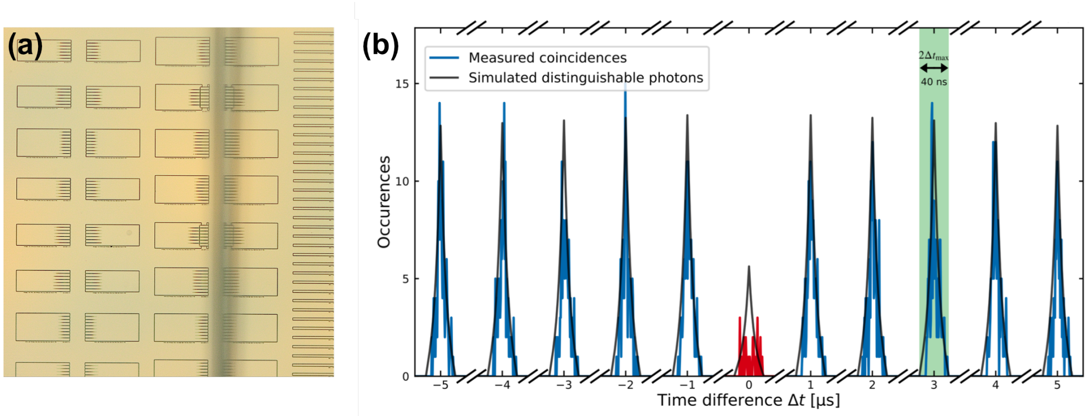

Fig. 1. (a) Microscope image showing the chiplets containing the waveguides and the vertical MW wire. (b) Two-Photon Quantum Interference between two remote tin-vacancy centers. Simultaneous detection events of photons at two single-photon detectors after quantum interference at a central beam-splitter. Blue lines show the coincidence events at a certain time difference and black the simulated distribution for fully distinguishable photons. The vanishing counts of the central time-bin (red) signify the degree of indistinguishability of the photons. The green shaded area indicates the maximum correlation distance, given by the detection time-window.

further investigation, either by improved fabrication methods, more stringent charge-resonance checks or time-filtering. Combining the single-photon emission with microwave-based spin control, remote-entanglement generation should be within reach.

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