Group-IV-vacancy centers in diamond: qubits for quantum networks

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For many applications in the field of quantum information processing stationary qubits are required, providing long-lived spin coherence and suitable level schemes for coherent control and efficient optical read out. In addition, transferring the spin information to indistinguishable single photons is necessary e.g. to distribute entanglement in quantum networks.

Color centers in diamond, more specifically the group-IV-vacancy centers, have emerged as promising candidates among solid state qubits. They exhibit favorable properties such as individually addressable spins with long coherence times and bright emission of single, close to transform limited photons. Recent experiments have shown that the negatively charged tin-vacancy center (SnV) [1] combines long spin coherence times at conveniently achievable cryogenic temperatures (>1K) [2-5] with truly lifetime-limited transition linewidths down to 20 MHz [1].

As with many solid-state defects, the coherent optical control and efficient single photon emission requires stable charge states of the defect. We explore the charge stability of the SnV(-) center for defects in the bulk and closer to the diamond surface and devise a method for charge state stabilization by illumination with a second light field. We find that the charge stabilization requires the presence of additional defects such as di-vacancies in the bulk or sp^2 defects on the surface and show evidence for this effect to be universal to all group-IV-vacancy centers. The charge-stabilized SnV(-) center exhibits exceptional spectral stability with very small spectral diffusion (< 5 MHz on a homogenous linewidth of 32 MHz over 21 hours) and promising spin dephasing (5 µs) and spin coherence (10 ms) times. We discuss prospects of coherent spin manipulation and generation of indistinguishable single photons.

The application of optically controlled qubits within building blocks of fiber-based quantum networks furthermore requires that the emitted photons have a wavelength in the low-loss telecom C-band around 1.5 µm. We demonstrate quantum frequency conversion for photons at the emission wavelength of SiV and SnV centers in diamond to the telecom C-band with high efficiency and ultra-low noise [6], paving the way for group-IV-vacancy centers as qubits for quantum networks.

References

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