Interfacing single color centers in diamond for quantum networks

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Color centers in diamond, i.e. atomic-scale, optically active defects in the diamond lattice, have received large recent attention as versatile tools for solid-state-based quantum technologies. The most prominent example is the nitrogen vacancy (NV) center providing very long spin coherence times. On the other hand, its optical properties are limited by a dominant emission into a very broad phonon sideband hindering efficient optical spin access. Thus, identifying a spin impurity which offers sufficient quality in both photonic and spin properties remains a challenge. Silicon vacancy (SiV) centers have attracted large interest due to their spin-accessible optical transitions [1] and the quality of their optical spectrum, i.e. narrow zero phonon lines and weak phonon sidebands [2].

I will report on all-optical access to SiV spin coherence in the ground state using coherent population trapping [3]. Further, by employing ultrafast, all-optical coherent control we demonstrate Rabi oscillations and Ramsey interference between the ground and the excited state of the SiV as well as Raman-based Rabi rotations and Ramsey interference within the ground state manifold [4]. These measurements prove the accessibility of the complete set of single-qubit operations relying solely on optical fields and pave the way for high-speed QIP applications using SiV centers. Eventually, for interfacing to photons I will present deterministic coupling of single SiV centers to photonic crystal cavities directly fabricated in the diamond material [5].

The long-range transmission of photons from single quantum emitters such as color centers or quantum dots commonly suffers from large losses in standard optical fibers as the wavelengths usually do not fall within the low-loss telecommunication window. Hence, techniques are necessary to bridge the gap between the common NIR emission and the telecom spectral regions. A possible technique is quantum frequency conversion (QFC) of single photons based on the nonlinear process of difference frequency mixing. I will present experiments demonstrating that single photons from various sources can be frequency-down-converted from VIS/NIR wavelengths to telecom bands with efficiencies > 30% and signal-to-noise ratios > 100. We demonstrate that the QFC process preserves classical and quantum properties of the photons, such as coherence (g1), photon statistics (g2) [6], temporal correlation, indistinguishability, and polarization entanglement. QFC thus provides a powerful toolbox for interconnecting dissimilar quantum systems.

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