SFB/TRR 21 - Colloquium

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Quantum light-matter interfaces based on rare-earth-doped crystals and nano-photonics

Quantum light-matter interfaces that reversibly map the quantum state of photons onto the quantum states of atoms, are essential components in the quantum engineering toolbox with applications in quantum communication, computing, and quantum-enabled sensing. In this talk I present our progress towards developing on-chip quantum light-matter interfaces based on nanophotonic resonators fabricated in rare-earth-doped crystals known to exhibit the longest optical and spin coherence times in the solid state. We recently demonstrated coherent control of neodymium (Nd^{3+}) ions coupled to yttrium orthosilicate Y_2SiO_5 (YSO) photonic crystal nano-beam resonator. The coupling of the Nd^{3+} 883 nm $^4I_{9/2}$ - $^4F_{3/2}$ transition to the nano-resonator results in a 40 fold enhancement of the transition rate (Purcell effect), and increased optical absorption (80%) - adequate for realizing efficient optical quantum memories via cavity impedance matching. Optical coherence times T_2 up to 100 μm with low spectral diffusion were measured for ions embedded in photonic crystals, which are comparable to those observed in unprocessed bulk samples. This indicates that the remarkable coherence properties of REIs are preserved during nanofabrication process. Multi-temporal mode photon storage using stimulated photon echo and atomic frequency comb (AFC) protocols were implemented in these nano-resonators. Our current technology can be readily transferred to Erbium (Er) doped YSO devices, therefore opening the possibility of efficient on-chip optical quantum memory at 1.5 μm telecom wavelength. Integration with superconducting qubits can lead to devices for reversible quantum conversion of optical photons to microwave photons.

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