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State-of-the-art Quantum Dot-based Single-photon Sources for Quantum Key Distribution in Silica Fiber Networks at 1550 nm

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Optical fiber-based quantum network connecting remote nodes forms the backbone to implement ultra-secure data exchange protocols and schemes, utilizing a quantum state of a single photon. Notably, for such quantum networks existing silica-fiber-based infrastructure can be used, where the spectral window around 1550 nm provides a low-loss photon transmission channel for long-haul communication. Moreover, one can benefit from existing devices and classical signal management protocols, simplifying the preparation, encoding and transfer of quantum states. Devices producing single photon states on demand are considered key building blocks of future quantum networks. While several single-photon sources (SPS) operating in the telecom C-band, including sources based on non-linear frequency conversion or emerging materials, have been demonstrated to date, semiconductor quantum dots (QDs) are among the most promising candidates, enabling exceptional performance and engineered photonic devices.

In this presentation, we show a deterministically-fabricated optically-triggered SPS emitting in the telecom spectral range near 1550 nm. The SPS consists of a single pre-selected self-assembled InAs/InP QD embedded in a circular Bragg grating cavity for Purcell-enhanced emission of the embedded quantum emitter. The applied deterministic fabrication technique results in a high device yield in combination with excellent quantum-optical properties, paving the way for scalable applications in photonic quantum information technologies. The high Purcell enhancement with $F_{\mathrm{p}} = 5$ realized in our device, shows potential for single photon generation at GHz rates. Moreover, the cavity's far-field emission pattern allows for efficient photon extraction close to 17% at the numerical aperture 0.4, which can be further optimized for the coupling to single-mode fibers. The device provides high single photon emission purity with $g^{(2)}(0) = 3.2\times10^{-3}$ at $T = 4.2$ K, while still supporting a good performance ($g^{(2)}(0) = 0.2$) at elevated temperatures ($T = 50$ K) accessible with compact Stirling-type cryocoolers. Finally, Hong-Ou-Mandel-type two-photon interference (TPI) experiments reveal record-high photon indistinguishabilities of 19% in the as-measured case and 99.8% with temporal post-selection.

Finally, we evaluated our SPS in a test environment for its potential implementation in polarization-encoded BB84 quantum key distribution (QKD) in silica fiber networks. A careful benchmarking of the performance of our source compared with previous single-photon QKD experiments reveals that transmission distances in excess of 100 km can be expected in full implementations.