Integrated Quantum Photonics

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Quantum information processing is an emerging field which promises secure communication or computational speed-ups for certain important computational problems if they are tackled with quantum computers. This has stimulated intense research on a variety of quantum bit (qubit) carriers and quantum technological platforms. Single photons are a prime qubit for the propagation and processing of quantum information, as they can be transmitted over long distances with low loss and manipulated by linear optical elements. However, the production, processing and detection of single photons is still mostly realized using bulky free-space or fiber-optic devices, posing severe challenges if more complex quantum circuits with high functionality going beyond a few photonic qubits are considered. Waveguide integrated quantum photonic circuits provide a route to overcome such limitations [1], where we target in this work the full integration of active and passive quantum devices on a single GaAs chip.

For the development of a quantum integrated photonics platform on GaAs, we develop a waveguide platform for the integration of single photon sources based on InGaAs quantum dots (QDs), superconducting single photon detectors, electro-optic tuners, directional couplers and splitters. Single-photon sources coupled to waveguides are realized by embedding QDs in photonic crystal cavities [2] (see Fig. 1). In order to tune individual QDs spectrally for indistinguishable photon emission, on-chip electrical control is established. Waveguide single-photon detectors are demonstrated by patterning superconducting NbN nanowires on top of ridge waveguides, resulting in high efficiency and low jitter [3]. They can also be arranged to implement on-chip photon auto-correlation measurements [4] or photon number resolved detection [5]. The presented building blocks are a key for integrated quantum photonics based quantum information processing and results towards this goal and key features of this platform will be presented.

In conclusion, we have demonstrated the key building blocks of a scalable quantum photonic integrated circuit. They are based on the same GaAs/AlGaAs material basis and therefore can be integrated on the same chip. This should open the way to solid-state quantum processing with several tens of qubits.

Fig. 1. Photonic crystal waveguide structure with integrated quantum dots for on-chip single photon generation.