Quantum light sources for foundational tests and quantum communication

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Single photons and entangled states of light have been instrumental to the investigations into the foundations of quantum physics, which in turn led to the creation of the field of quantum information science and the resulting quantum technologies. Major advances in quantum photonics, such as the various generations of Bell inequality tests, could often be attributed to a new and improved quantum light source. Likewise, for optical quantum technologies, especially in quantum communication, source performance is as important as detector technology.

In our research we have been developing semiconductor waveguide sources of photon pairs and semiconductor quantum dots as sources of single photons and entangled photon states. Depending on the intended application in a quantum information processing protocol or foundational test there are a number of specifications that such a source must fulfil, such as the emission rate, -efficiency, and -statistics, state purity, indistinguishability, spectral and time properties, etc.

Achieving the desired characteristics not only requires designing and fabricating innovative devices, but also engineering the excitation of the quantum emitter or nonlinear element that is at the heart of the source. While much work has gone into adapting quantum optical coherent control techniques invented for atoms and molecules towards solid-state environments, also completely new methods have emerged that help avoid or mitigate unwanted decoherence mechanisms. For example, we have implemented the so-called Swing-up of Quantum Emitter Population (SUPER) scheme and Adiabatic Rapid Passage (ARP) in single quantum dots. Furthermore, we have been able to coherently excite and control dark states, which will be useful in entanglement generation and as quantum memories.