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Narrow-band Photons for Quantum Information

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ABSTRACT:

This thesis is summarizing my years spent at the University of Vienna, designing and building single photon sources for investigating light-matter interactions.

These efforts are highlighted in the included publications and involve tailoring the spectral properties of single photons to atomic systems, introducing an interface for the photons and atoms, and exploring quantum information applications for photonic states with extended coherence length.

Since atomic transitions set demanding specifications on photons' frequency and bandwidth we designed and built a novel source of photons based on cavity-enhanced spontaneous parametric down-conversion which is capable of emitting single- and multi-photon states with comparable bandwidth and frequency to that of the Cesium atoms' D2 transition (852 nm).

Our source does not require additional complicated mode filters to operate in single frequency mode and shows dramatic enhancement in brightness and robustness.

On the interface side, we studied trapping atoms in the evanescent field of laser-written waveguides close to the host chip's surface. We devised a method for characterizing the extent of the evanescent field and introduced a trapping method based on that.

A major obstacle of employing integrated optics is the in- and out- fiber coupling to them. For laser-written waveguides, the coupling is typically limited to about 50% due to the mode-field diameter mismatch. This poses an obstacle for coupling in the photons from the source and coupling them out to the detectors.

We proposed using thermally expanded core (TEC) fibers to match the mode-field diameters of the fibers to the waveguides (which are typically about two times larger) to bypass this issue. Theoretically, this technique allows for perfect mode-matching and diminishes the fiber coupling issue of the laser-written waveguides.

Narrowband photons emitted from our source provide a remarkable coherence length, and thus coherence times that are about 18.7 ns. This feature opens up temporal measurements with high resolution by surpassing the intrinsic timing jitter of single-photon detectors, which is typically about 0.5 ns.

We investigated applications which can benefit from this feature, one of which reported here is the superposition of quantum circuits and experimental super-position of causal orders of quantum gates.