Sub-Megahertz Linewidth Single Photon Source Suitable for Quantum Memories

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Hybrid quantum technologies seek to combine the advantages of two individual quantum architectures by transferring the information between the two systems. We want to benefit from the high mobility and ease of transmission of photons for quantum communication and exploit the excellent readout and storage capabilities of atomic qubits as a quantum memory, which is essential to build up quantum repeater networks for quantum data processing. Efficient interaction of photons with atoms requires a match of the photons spectral properties to those of the resonances of the atomic species. The atomic transition usually has a much narrower bandwidth than single photons generated by spontaneous parametric down-conversion (SPDC), the current gold standard of producing high-purity heralded single photons at flexible wavelengths. To develop hybrid quantum technologies therefore requires significantly reducing the single photon emission spectra to fulfill these requirements. The way we try to achieve this is by using an optical cavity to enhance the probability of creating the photons in the spectral and spatial resonator mode.

We report 100% duty cycle generation of sub-MHz single photon pairs at the Rubidium D_1 line using cavity-enhanced spontaneous parametric down-conversion [1]. The double exponential decay of the temporal intensity cross-correlation function exhibits a bandwidth of 429 ± 10 kHz for the single photons, an order of magnitude below the natural linewidth of the target transition. This is, to our knowledge, the narrowest bandwidth of single photons from SPDC to date. A new method of placing a half-wave plate inside the cavity helps to achieve triple resonance between pump, signal and idler photon, reducing the bandwidth and simplifying the locking scheme. Additionally, stabilisation of the cavity to the pump frequency enables the 100% duty cycle. The quantum nature of the source is confirmed by the idler-triggered second-order autocorrelation function at $\tau = 0$ to be $g^{(2)}_{s,s}(0) = 0.032 \pm 0.003$ for a heralding rate of 3.5 kHz and antibunching below 0.5 is observed up to heralding rates of 70 kHz [1]. The high purity of the source is matched by high indistinguishability of the photons demonstrated in a Hong-Ou-Mandel (HOM) interference experiment with a visibility $V = 96.7 \pm 3.4$ %. Additionally, the mode-locked two-photon state of the generated pairs leads to revivals of the HOM dip. We observe these revivals up to 100 m path difference between signal and idler photon, independently proofing the long coherence length of our photons.

References

1. M. Rambach, A. Nikolova, T. J. Weinhold, and A. G. White, "Sub-megahertz linewidth single photon source," APL Photonics **1**, 096101 (2016).