Spectral Compression of Narrowband Single Photons with a Near Resonant Cavity

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Abstract: We compress the spectrum of narrowband heralded single photons generated by four-wave mixing in cold ^{87}Rb atoms using a near-resonant cavity as dispersion medium, without reducing the brightness and almost matching the atomic linewidth.

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1. Introduction

Efficient atom-light interactions at the single quantum level requires matching the bandwidth of the traveling photon with the atomic absorption linewidth. A common way to match the two bandwidths is to narrow the single photon spectrum with a filter, with the unavoidable consequence of reducing the brightness. Inspired by techniques to compress ultra-fast pulses [1, 2] we developed a method to compress the bandwidth of already narrowband photons using an asymmetric cavity as dispersion medium without, in principle, reducing the brightness.

2. Experiment

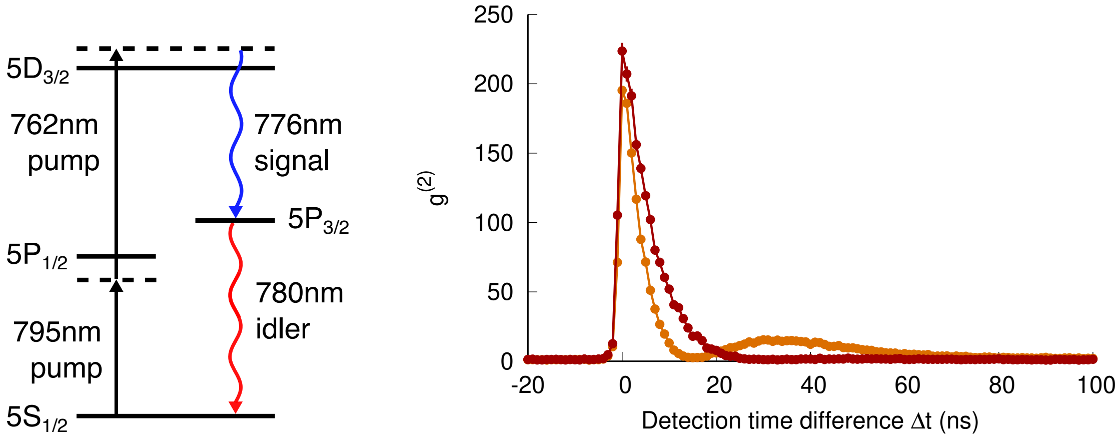

Fig. 1. (Left) Cascade level scheme for the generation of photon pairs in ^{87}Rb. (Right) Second order time correlation of the photon pairs generated by four-wave mixing before (red) and after (orange) the dispersion cavity.

We obtain heralded single photons at 780 nm from the photon pairs generated by four-wave mixing based on a cascade decay in a cold cloud of ^{87}Rb (Fig. 1(Left)). Due to collective effects in the atomic cloud [3], the spectrum of the heralded photon, measured with a fabry-perot cavity with linewidth of 2.7 MHz and reported in Fig. 2, has a bandwidth of $\approx$ 20 MHz, broader than the natural atomic linewidth of 6 MHz.

The spectral compression of a single photon requires a large dispersion of the spectrum and the time modulation of the phase envelope of the wavepacket. A near-resonant asymmetric cavity with a bandwidth of 7.3 MHz introduces the large dispersion necessary for the compression, followed by an electro-optical modulator (EOM) to reshape the phase envelope. We use the heralding signal to synchronize the single photon wave packet with the EOM modulation.

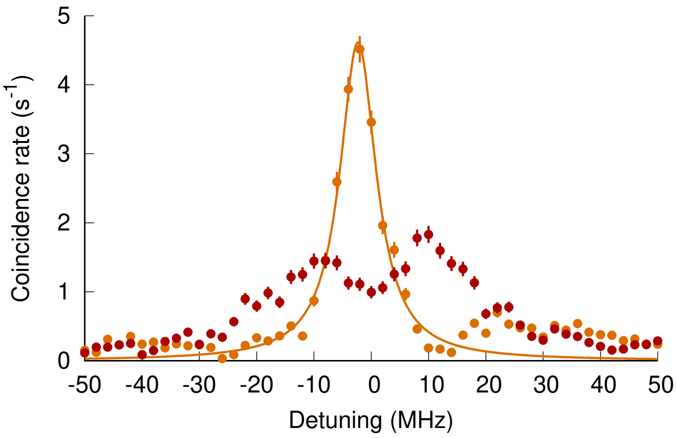

Fig. 2. Spectral profile of heralded photons with (orange) and without (red) compression. The solid line is a Lorentzian with full-width half maximum of 8 MHz.

3. Conclusion

After the compression we observe a narrower heralded photon spectrum (Fig. 2). We fit it to a Lorentzian profile and estimate a full-width half maximum of 8 MHz almost matching 6 MHz, the natural linewidth of the D2 transition of ^{87}Rb.

We believe that this technique is a useful resource to relax the bandwidth requirements on the narrowband single photon sources.

References

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