Progress on on-demand single photon source based on room-temperature vapour cells

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Quantum repeater protocols like the DLCZ protocol [1] using atomic ensembles have been developed to circumvent photon transmission losses, that hamper direct, long-range quantum communication. Even though the DLCZ protocol has been demonstrated in cold atomic ensembles, the demand for scalability favours room-temperature solutions. Typically, the coherence times of room-temperature systems are limited due to atomic motion. As opposed to previous ensemble-based experiments, which typically rely on performing operations sufficiently fast to have quasi-stationary atoms, we employ motional averaging where atoms move in and out of the beam several times during the interaction while maintaining the phase information for much longer than the interaction time [2]. In our experiment we use caesium atoms at room temperature contained in microcells with spin-protecting coating in combination with a cavity around the microcell to enhance the light-matter interaction. By suitable spectral filtering we erase the "which atom" information and obtain an efficient and homogenous coupling between all atoms and the light. Photon-heralded single excitations can be created and stored as collective spin-waves on a timescale given by the spin coherence time. We have demonstrated efficient creation and readout of collective excitations with a lifetime up to $0.27 \pm 0.04\,\mathrm{ms}$, two orders of magnitude larger than previously achieved for single excitations in room-temperature sources. We experimentally verify the non-classicality of the light-matter correlations by observing a violation of the Cauchy Schwarz inequality with $R = 1.4 \pm 0.1 > 1$. Through spectral and temporal analysis we identify four-wave mixing as the main intrinsic noise contribution compromising single photon operation of the source.

[1] L.-M. Duan, M. D. Lukin, J. I. Cirac and P. Zoller, *Long-distance quantum communication with atomic ensembles and linear optics*, Nature, **414**, 413 (2001)
[2] J. Borregaard, M. Zugenmaier, J. M. Petersen, H. Shen, G. Vasilakis, E. S. Polzik and A. S. Sørensen, *Scalable photonic network architecture based on motional averaging in room temperature gas*, Nature Communications, **7**, 11356 (2016)
[3] M. Zugenmaier, K. Dideriksen, A. S. Sørensen, B. Albrecht and E. S. Polzik, *Long-lived non-classical correlations for scalable quantum repeaters at room temperature*, pre-print, arXiv:1801.03286 (2018)