Multimode quantum memory in cold rubidium atoms

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Most applications such as the DLCZ protocol, enhanced photon generation, or even linear optical quantum computing require or greatly benefit from a multimode quantum memory. We want to demonstrate results from our quantum memory in cold rubidium atoms at temperature 22 ± 2 μK generated within a magneto-optical trap [1]. The experimental realization is accomplished through multiplexing of angular emission modes of a single quantum memory and by employing a spatially resolved single-photon detection. Obtained results are much better than in our previous work with warm rubidium vapours [2, 3]. Our experimental setup generates photons in 665 pairwise-coupled modes, exploring the regime of multimode capacity with simultaneous extremely low noise-level achieved with simple and robust filtering.

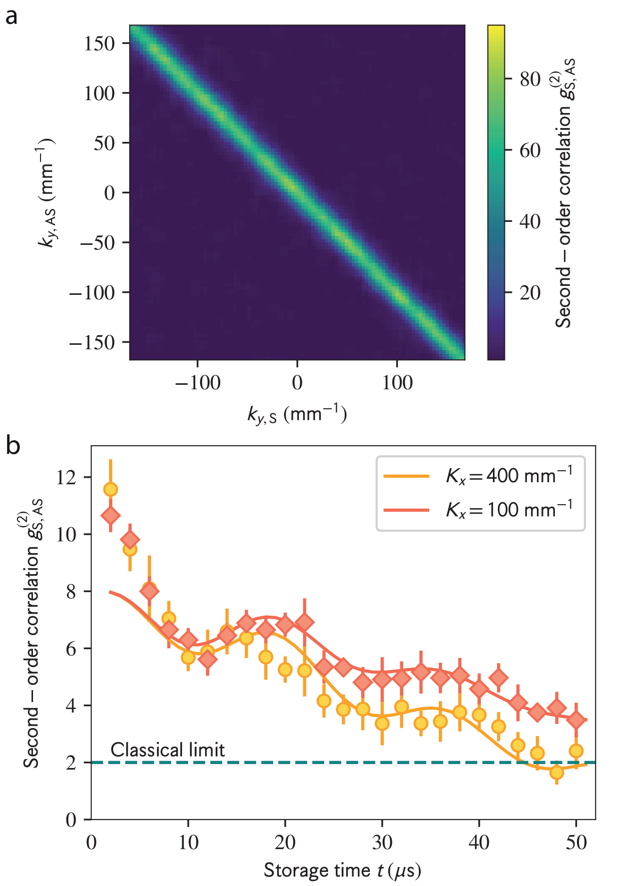

Figure 1: Nonclassical correlations of photons emitted from the quantum memory. **a** Second-order cross-correlation function $g^{(2)}_{S,AS}$ measured for different positions of region of interests in Stokes and anti-Stokes arms, for zero memory storage time. **b** Second-order correlation as a function of storage time, measured for two different angles of scattering corresponding to stored spin waves with different K_x.

We use a single-photon resolving camera to measure both correlations and autocorrelation. The average value of the second-order correlation function $g^{(2)}_{S,AS}$ equals 72 ± 5 which unambiguously proves quantum character of light. We achieved the quantum memory lifetime more than 50 μs, which combined with the multimode capacity invites real-time feedback processing of stored excitations and paves the way toward promptly achieving fast generation of single- and multi-photon states. Moreover we observed interference of two spin waves resulting with oscillation of $g^{(2)}_{S,AS}$ in presence of external magnetic field.

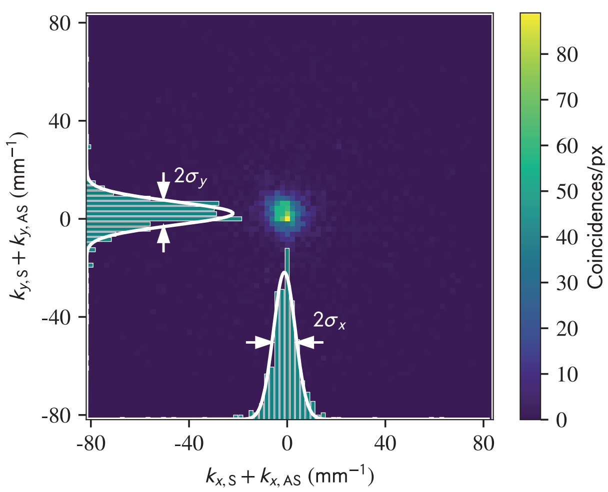

Figure 2: Stokes-anti-Stokes coincidences obtained from 10^7 frames, counted in the center-of-mass variables $(k_{x,S} + k_{x,AS})$ and $(k_{y,S} + k_{y,AS})$ for zero memory storage time.

[1] M Parniak, M Dąbrowski, M Mazelanik, A Leszczyński, M Lipka, W. Wasilewski, Nature communications 8, 2140 (2017)

[2] M Dąbrowski, M Parniak, W Wasilewski, Optica 4, 272-275 (2017)

[3] R Chrapkiewicz, M Dąbrowski, W Wasilewski, Physical Review Letters 118, 063603 (2017)