852-nm Single Photon Sources Based on Single Cesium Atom and Cesium Rydberg Super-atom Trapped in Optical Tweezer

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Narrow-band 852-nm single-photon sources (SPS) are demonstrated based on single cold Cesium (Cs) atom and cold Cs Rydberg super-atom trapped in 1064-nm optical tweezer. For single atom approach, a single Cs atom is loaded into a 1064-nm far-off-resonance microscopic tweezer (FORT) from a single-atom magneto-optical trap (MOT), and prepared at the $6S_{1/2}$ |F = 4, m = +4> state and subsequently has been periodically excited by the high-repetition resonant 852-nm 5-ns pulse chain to the $6P_{3/2}$ |F' = 5, m = +5> state. Spontaneously radiated photons from |5', +5> to |4, +4> transition are collected and characterized by Hanbury Brown - Twiss (HBT) measurement. Strong photon anti-bunching, $g^{(2)}(\tau=0) = 0.09 \pm 0.01$, is demonstrated, and it confirms the single-photon characters. For Cs |5', +5> to |4, +4> cycling transition at 852 nm, the FORT magic wavelength has been calculated theoretically and verified experimentally to be 937.6 nm. The Hong-Ou-Mandel (HOM) two-photon interference measurement is utilized to evaluate the photon indistinguishability of our two SPS with 1064-nm FORT or 937.6-nm FORT. Preliminary experimental results in the 937.6-nm magic-wavelength FORT case indicate that the photon indistinguishability can be improved ~ 20%, compared with the 1064-nm FORT case.

For Rydberg super-atom approach, $\sim 10^4$ cold Cs atoms are loaded into a tightly-focused ellipse 1064-nm FORT from cold atomic ensemble after MOT + compress MOT + molasses phases, and prepared at the $6S_{1/2}$ |F = 4, m = 0> ground state. During the period for FORT switching off, ~100 Cs atoms in a transverse region with ~10 μm diameter inside the ellipse cold atomic cloud are excited by means of tightly-focused two-photon resonant 852-nm and 509-nm laser pulses with a single-photon detuning of +30MHz. In the case of the principal quantum number n of $nS_{1/2}$ Rydberg state is bigger enough, for example, $90S_{1/2}$, the Rydberg excitation blockade radius is larger than the 852-nm and 509-nm beam spots size (~10 μm), only one of ~100 Cs atoms can be populated at $90S_{1/2}$ Rydberg state because of Rydberg excitation blockade, and other atoms remain at $6S_{1/2}$ |4, 0> ground state. This is so called the single collective excitation Rydberg super-atom. After 650-ns storage time, the resonant 509-nm laser pulse reads out 852-nm single photon from Rydberg super-atom. The second-order correlation degree is measured to be $g^{(2)}(\tau=0) = 0.19 \pm 0.02$ by the HBT scheme, and this confirms single-photon characters. Also magic-wavelength tweezer for Cs $6S_{1/2}$ |4, 0> ground state and $90S_{1/2}$ Rydberg state is calculated theoretically. The magic-wavelength FORT for Rydberg super-atom approach will be implemented in the near future, and other efforts will be made to improve the photon purity, photon indistinguishability, and the photon extraction efficiency of SPS.

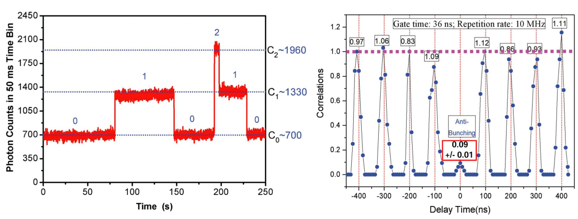

Fig. 1: *Single-atom tweezer case. Left: the fluorescence photon counts of Cesium MOT. Right: the normalized correlations vs the delay time.* $g^{(2)}(\tau=0)=0.09\pm0.01$.

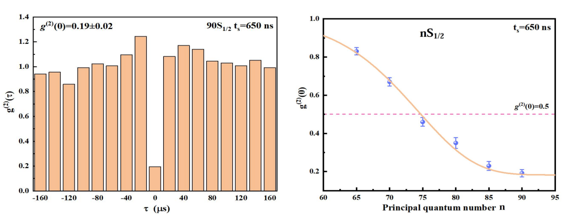

Fig. 2: *Cesium Rydberg super-atom case. Left:* $g^{(2)}(\tau)$ *vs the delay time* τ. $g^{(2)}(\tau=0)=0.19\pm0.02$ *for* $90S_{1/2}$. *Right:* $g^{(2)}(\tau=0)$ *vs n of* $nS_{1/2}$ *Rydberg states.*

Funding: This work is supported by the National Key Research & Development Program of China (2021YFA1402002).