Extraction of a single photon from an optical pulse

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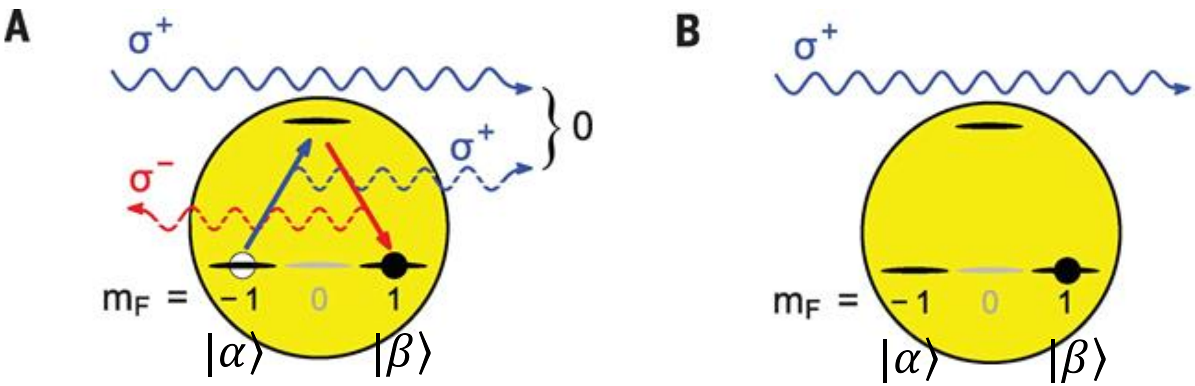
- Interaction between single photons and single atoms

- Analysis of Deterministic Swapping of Photonic and Atomic States Through Single-Photon Raman Interaction. *Physical Review A.* **95 (2017)**
- Deterministic Photon-Atom and Photon-Photon Interactions Based on Single-Photon Raman Interaction. *Laser Resonators, Microresonators, and Beam Control Xviii.* **9727 (2016)**

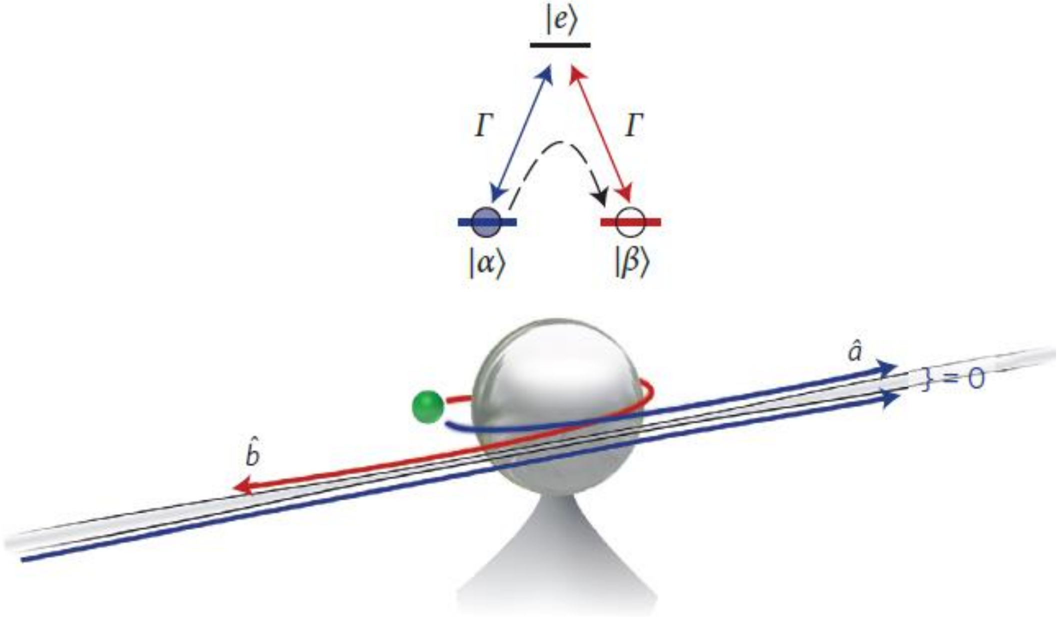
Single photon Raman interaction



- $\sim 30 \times 10^6\ Rb^{87}$ atoms at $\sim 7\mu K$
- 85ns measurement pulse of varying strength
- Erasure pulse which contains ~1.5 photons and ~15ns long

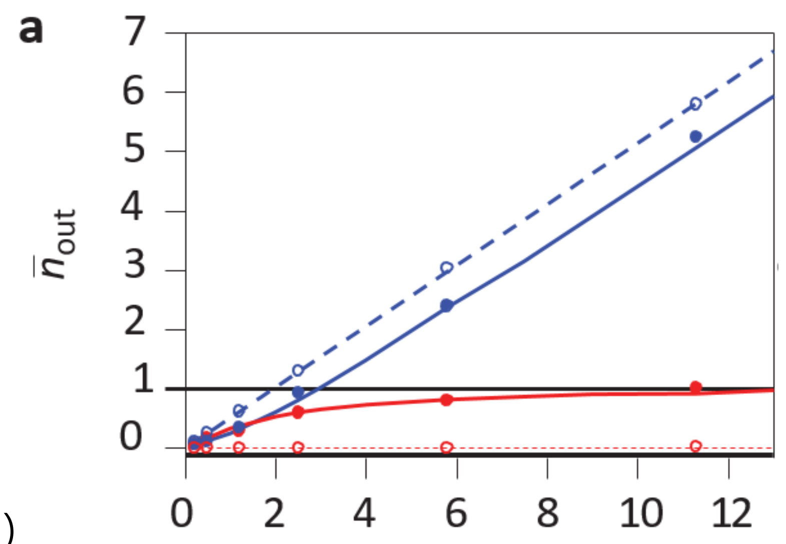
Experimental scheme

- g ~ 24 MHz, γ = 3 MHz, κ_{ex} = 40 MHz
- κ_i = 6.6 MHz -> 48% linear loss
- TM whispering gallery mode : 6 % of undesired polarization

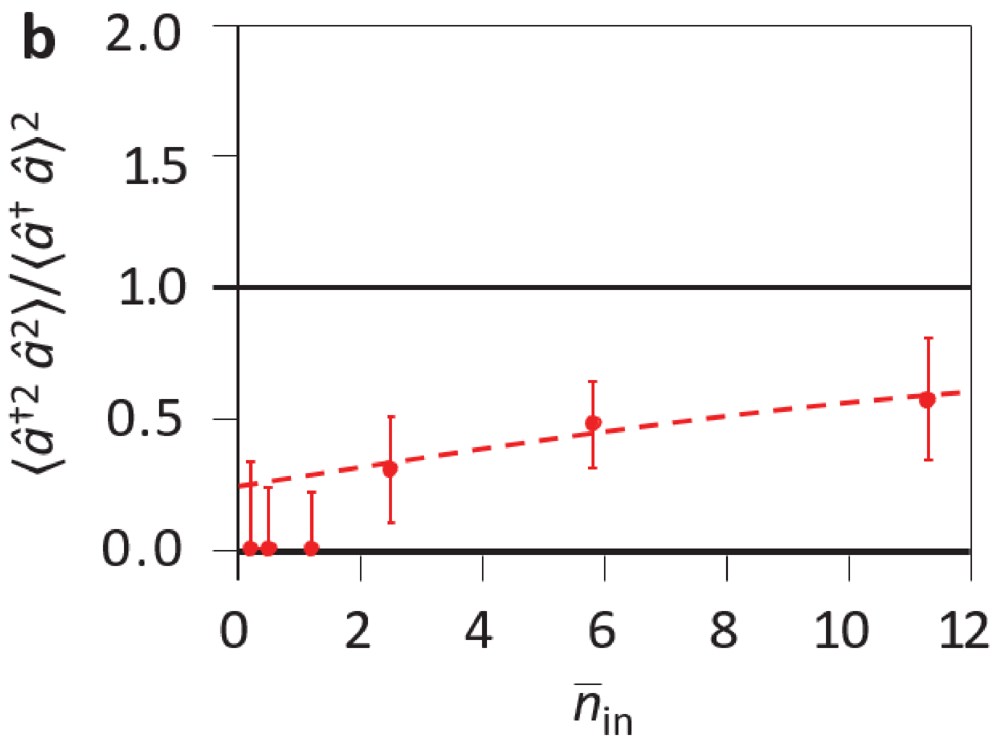


Mean number of photons

- Measured extraction efficiency ~ 40% ($n_{in} \ll 1$)
- Ideal extraction efficiency ~ 52% (due to 48% linear loss of the cavity)
- Loss can occur prior to the Raman passage of the atom to $|\beta\rangle$
- Expected # of reflected photons ~ 0.73 ($n_{in} \gg 1$)
- Measured # of reflected photons ~ 1 (n_{in} = 11) (due to interaction between ~4% undesired polarization and $|\beta\rangle$)



Two-photon detection prob.



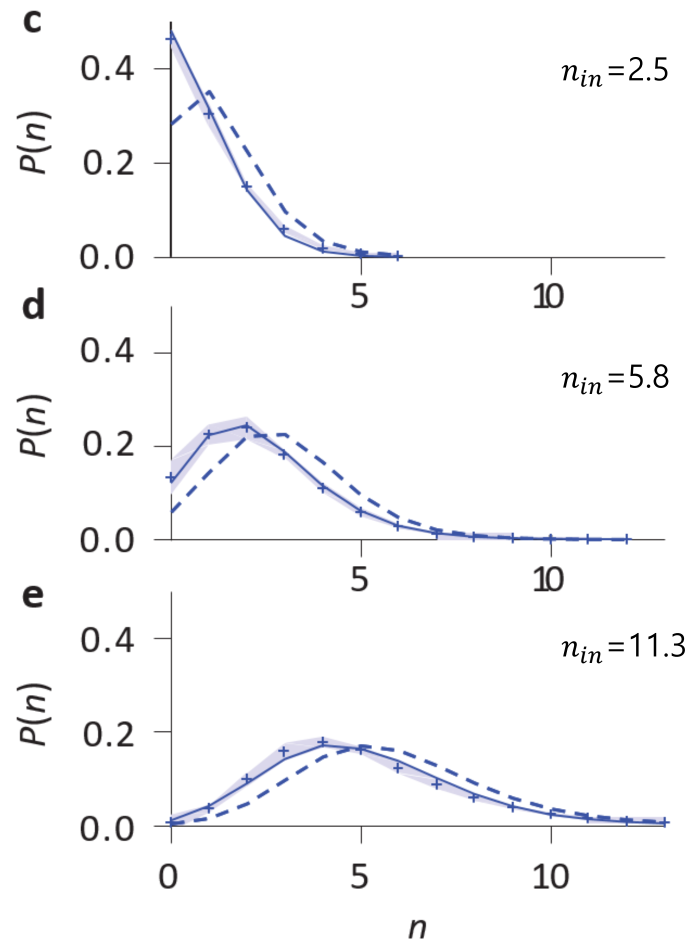
- $g^2(0)$ < 1(sub-poissonian) for all input photon numbers

Photon number distribution

- Retrieval of photon number distribution

$$P(n|k) = \frac{(N-N_d)!}{(N-N_d-n)!}\sum_{i=0}^{n}\frac{\left[1-\eta\left(1-\frac{i+N_d}{N}\right)\right]^k}{i!\,(n-i)!\,(-1)^{n-i}}$$

- k photons input, n photons detected
- N : # of detectors
- N_d: # of alive detectors



Limitation

- Photon loss (6.6MHz -> 0.5MHz)
- Variations in the coupling strength
- Polarization impurity

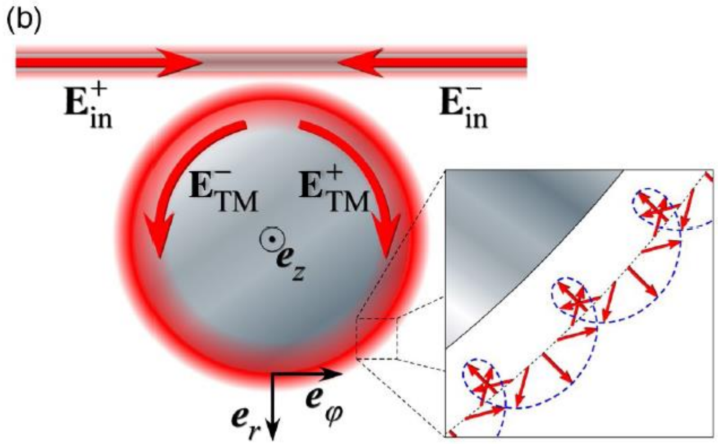
Summary

- Demonstrate the deterministic extraction of a single photon from a pulse

- Reflected photon is a single photon Fock state

Q&A

- Q : How can decide quantum axis of the atom?
- A : If light is sent from the left through the nanofiber, it couples to E_{TM}^{+} mode of which the magnetic field is perpendicular to wave vector. E_{TM}^{+} mode can be represented as $E_{TM}^{+} = |E_{trans}|e_r + |E_{long}|e_{\varphi}$ and microresonator made of silica has a property that $E_{TM}^{\pm}$modes almost overlap with circularly $\sigma^{\pm}$ polarized mode. And the quatization axis of the Rb atom is determined by the z-axis of input source. So, light pulse from the alternating direction will prepare the atom and subsequent pulse from the opposite side is used for photon subtraction.



Q&A

- Q : How to calibrate the input photon?
- A : According to the reference, it seems that they use nondestructive photon detection. (A. Reiserer, S. Ritter, G. Rempe, Science 342, 1349–1351 (2013))