Strong coupling between photons of two light field mediated by one atom

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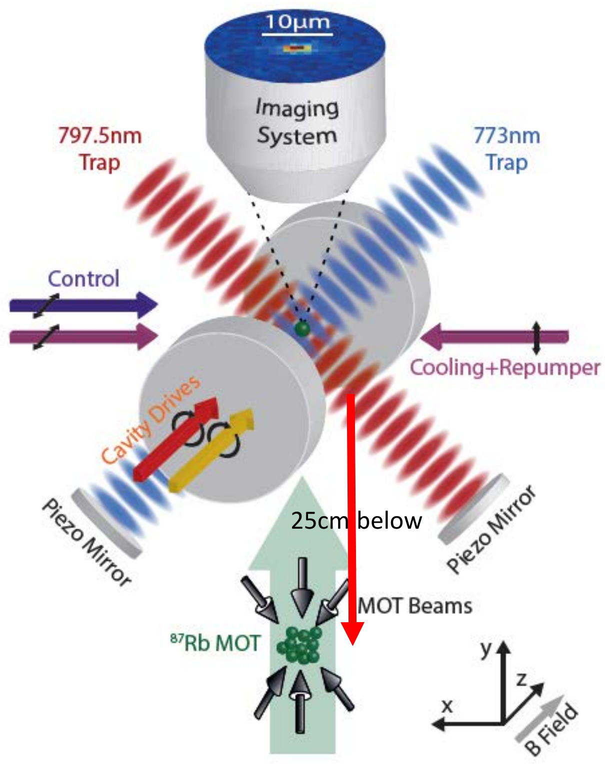
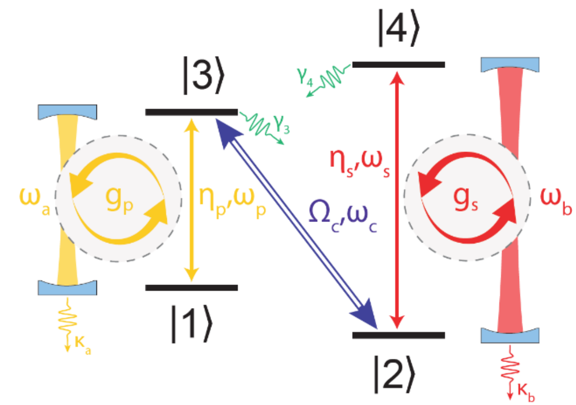
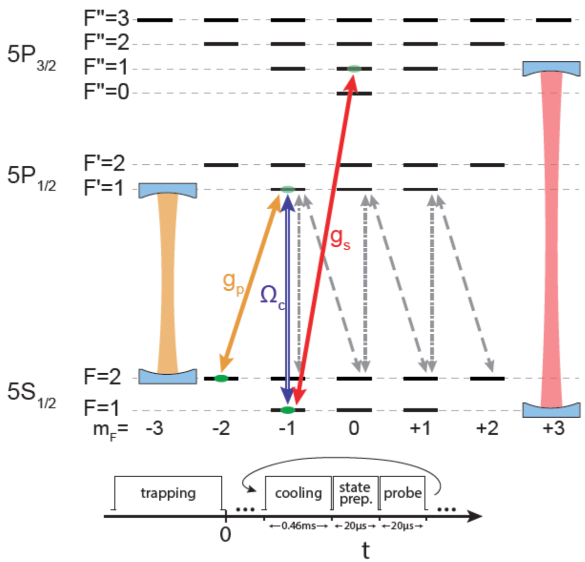
- 1^{st} author : C. Hamsen
- Recently, in 2017, he published a paper of title "Two photon blockade in an atom-driven cavity QED system" at PRL

Experimental Scheme





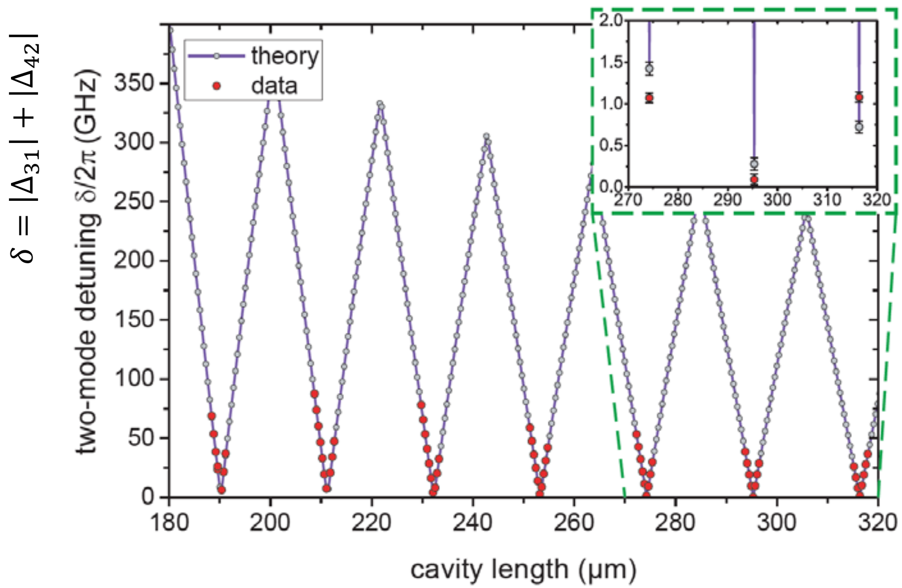


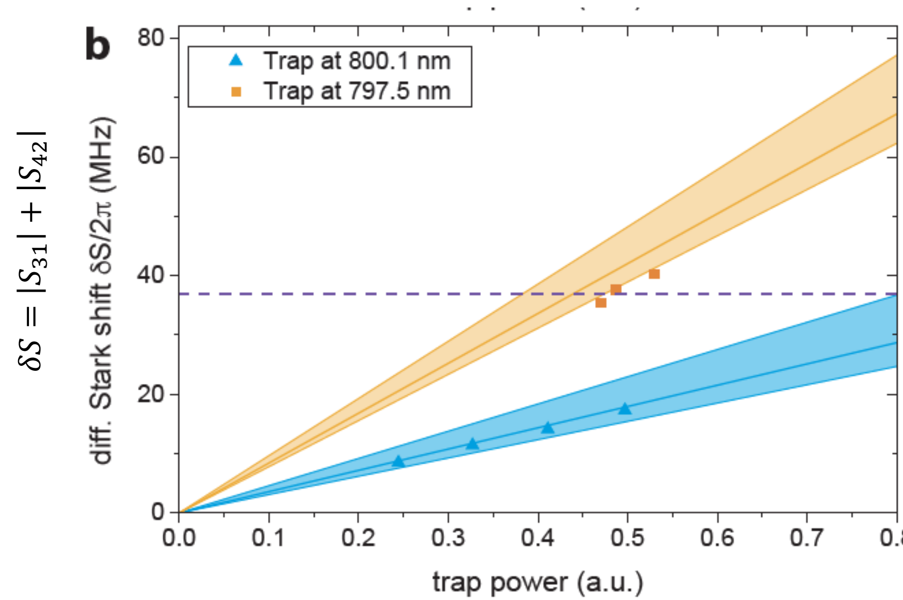
$(g_p, \kappa_a, \gamma_3)/2\pi$ = (10.1, 2.0, 2.9) MHz

$(g_s, \kappa_b, \gamma_4)/2\pi$ = (9.3, 1.5, 3.0) MHz

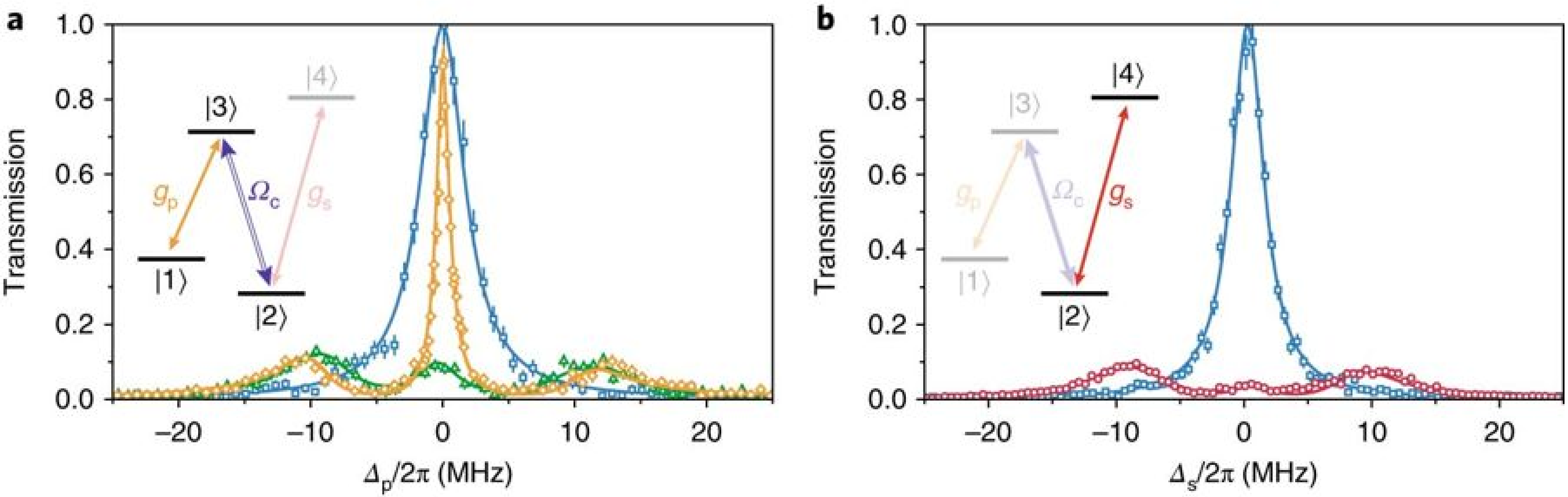
Cavity for two mode coupling

- $l = \frac{n_a \lambda_{31}}{2} = \frac{n_b \lambda_{42}}{2}$
- Increase the cavity length in steps of $\lambda_{42}/2$ (n_b->n_b+1)
- At cavity length 295um, probe transition is 37 MHz red-detuned to mode A, while signal transition is resonant to mode B
- This residual detuning is compensated by the dynamical Stark shift using the transverse dipole trap





Strong coupling regime



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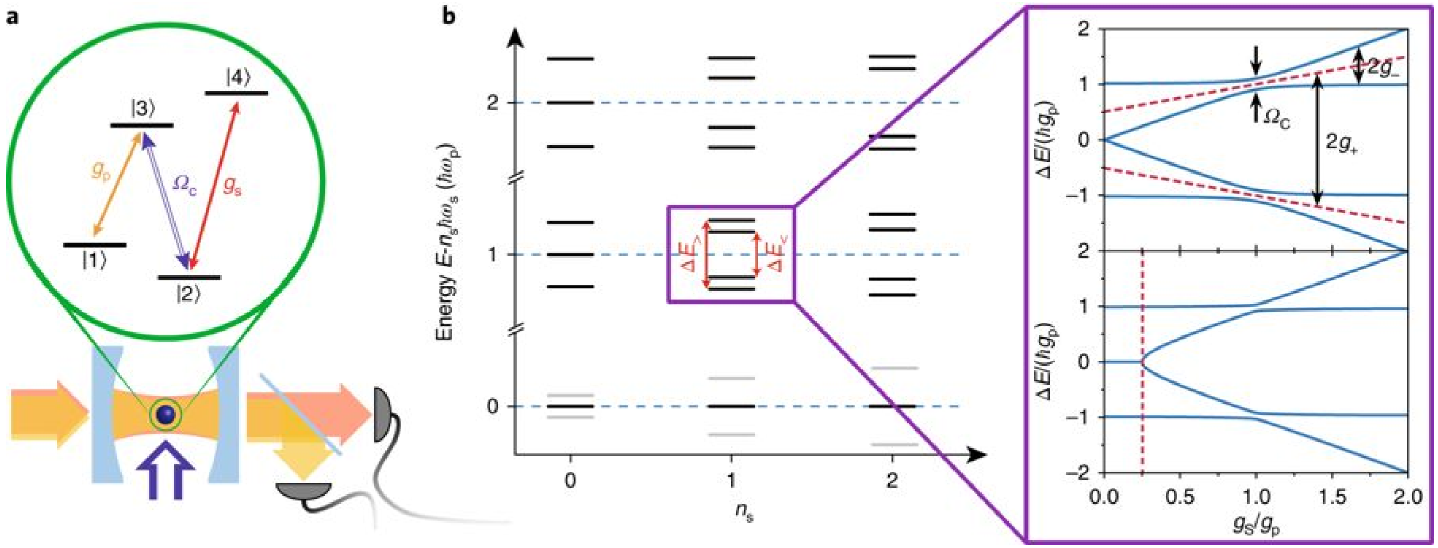
Energy level structure



$$\hat{H} = (\Delta_p - \Delta_c + \Delta_{31})\hat{\sigma}_{11}^\dagger\hat{\sigma}_{11} - \Delta_c\hat{\sigma}_{33}^\dagger\hat{\sigma}_{33} - (\Delta_s + \Delta_{42})\hat{\sigma}_{44}^\dagger\hat{\sigma}_{44} - \Delta_p\hat{a}^\dagger\hat{a} - \Delta_s\hat{b}^\dagger\hat{b} + g_p\left(\hat{a}^\dagger\hat{\sigma}_{13} + \hat{\sigma}_{13}^\dagger\hat{a}\right) + g_s\left(\hat{b}^\dagger\hat{\sigma}_{24} + \hat{\sigma}_{24}^\dagger\hat{b}\right) + (\eta_p\hat{a}^\dagger + \eta_s\hat{b}^\dagger + \Omega_c\hat{\sigma}_{23}^\dagger + \text{h.c.})$$

$$\Delta_p = \omega_p - \omega_a \quad \Delta_{31} = \omega_a - \omega_{31}$$
$$\Delta_s = \omega_s - \omega_b \quad \Delta_{42} = \omega_b - \omega_{42},$$
$$\Delta_c = \omega_c - \omega_{32},$$

$$\Delta E_{\gtrless}(n_p, n_s) = 2\hbar\left(g_+(n_p, n_s) \pm g_-(n_p, n_s)\right)$$
$$\text{with } g_\pm(n_p, n_s) = \frac{1}{2}\sqrt{\left(\sqrt{n_p}g_p \pm \sqrt{n_s}g_s\right)^2 + \Omega_c^2}$$

Mutual photon blockade

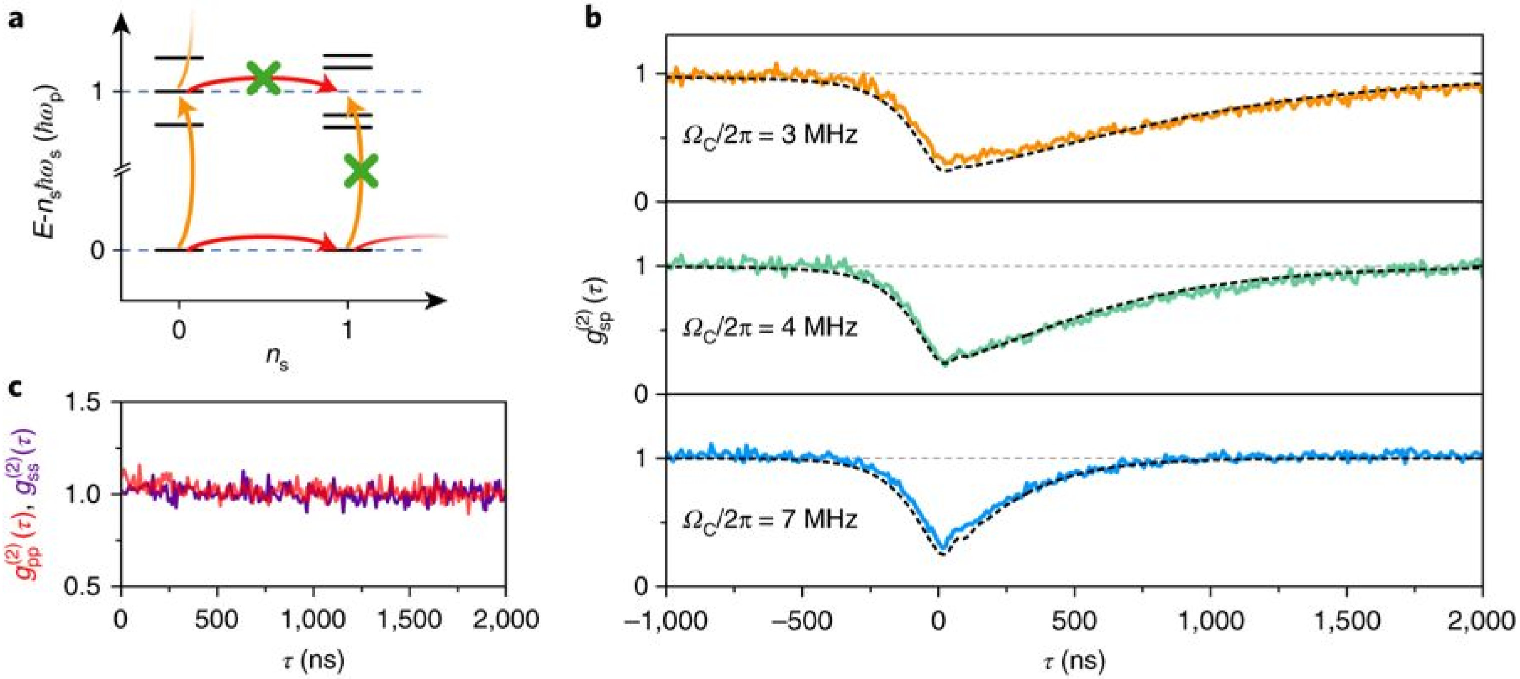
- Second-order cross-correlation $g_{sp}^{(2)}(\tau) = \langle n_s(0) n_p(\tau) \rangle / (\langle n_s \rangle \langle n_p \rangle)$

$g_{sp}^{(2)}(0) = 1$: uncorrelated

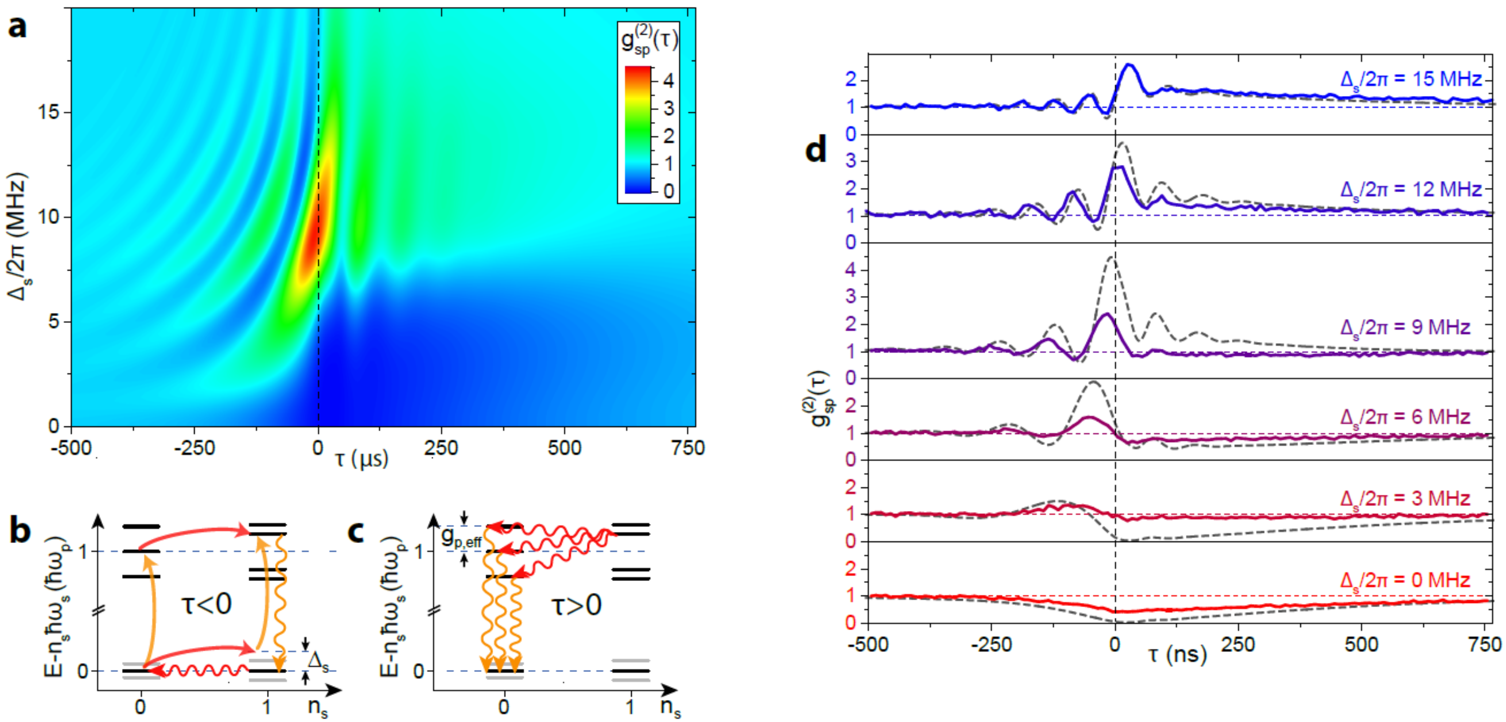
$g_{sp}^{(2)}(0) > 1$: correlated

$g_{sp}^{(2)}(0) < 1$: anti-correlated

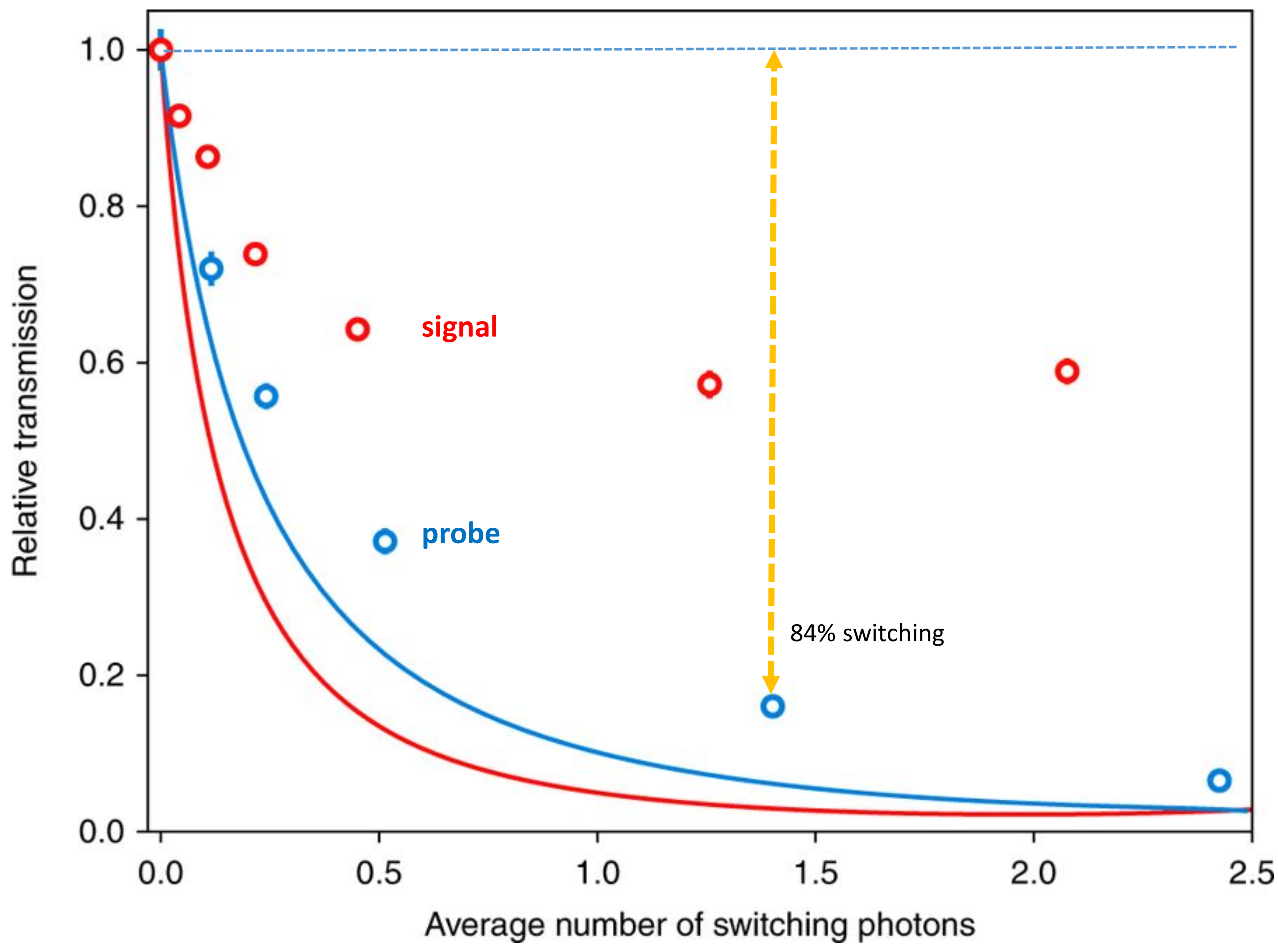
$\Delta_p = \Delta_s = 0$



Conjunct photon transit



Optical switching



Conclusion

- Demonstration of strong coupling between two light fields via interaction with a four level atom
- Photon-photon switching and strong correlations between two light fields
- Selective excitation of a specific manifold (n,1)

-> detection of a signal photon announces n photons in the probe mode

- Non destructive photon counting
- Instead of two modes in one cavity, crossed single mode cavities will be fine