RYDBERG ATOMS IN CAVITIES - QUANTUM FEEDBACK

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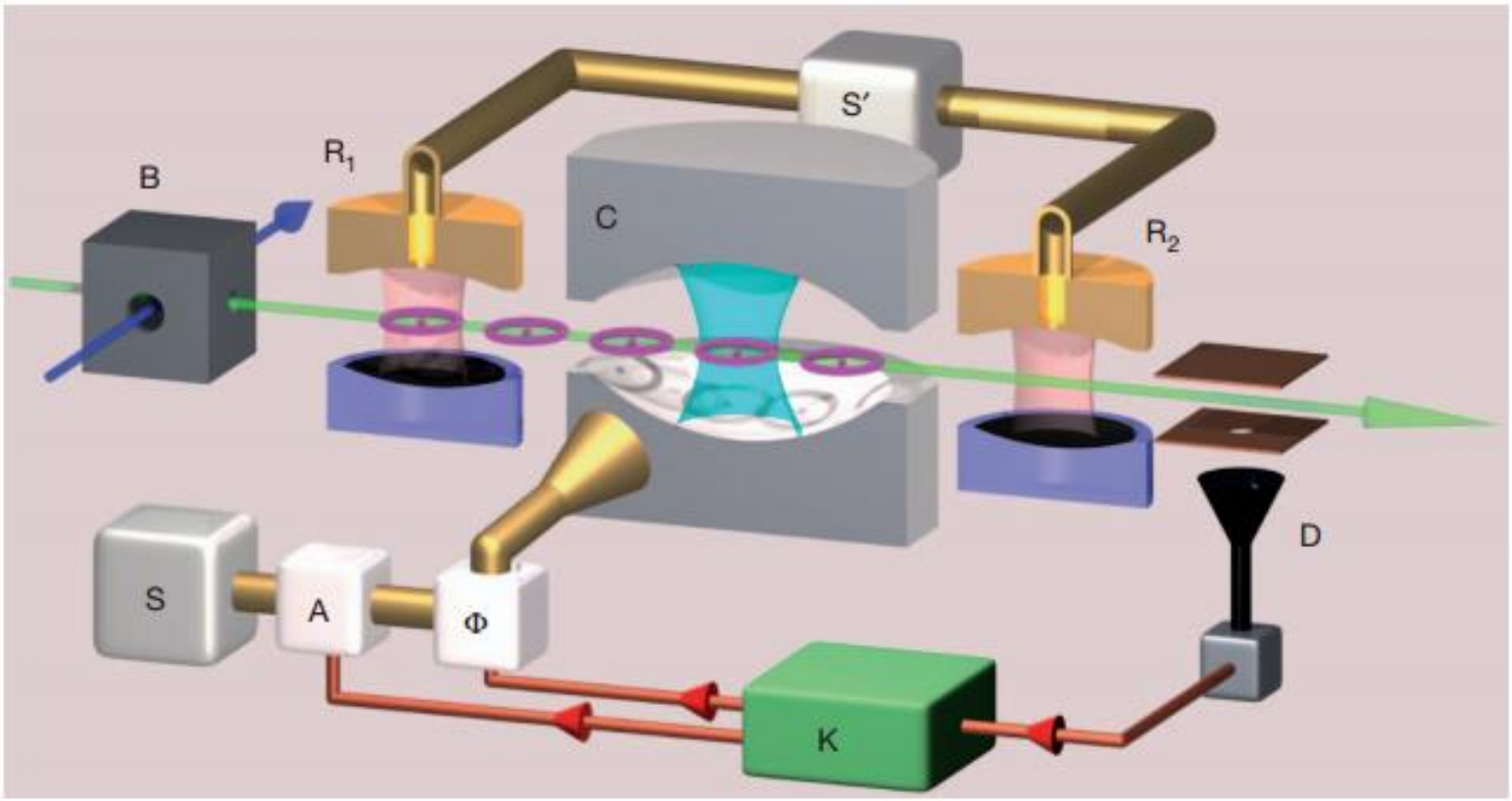
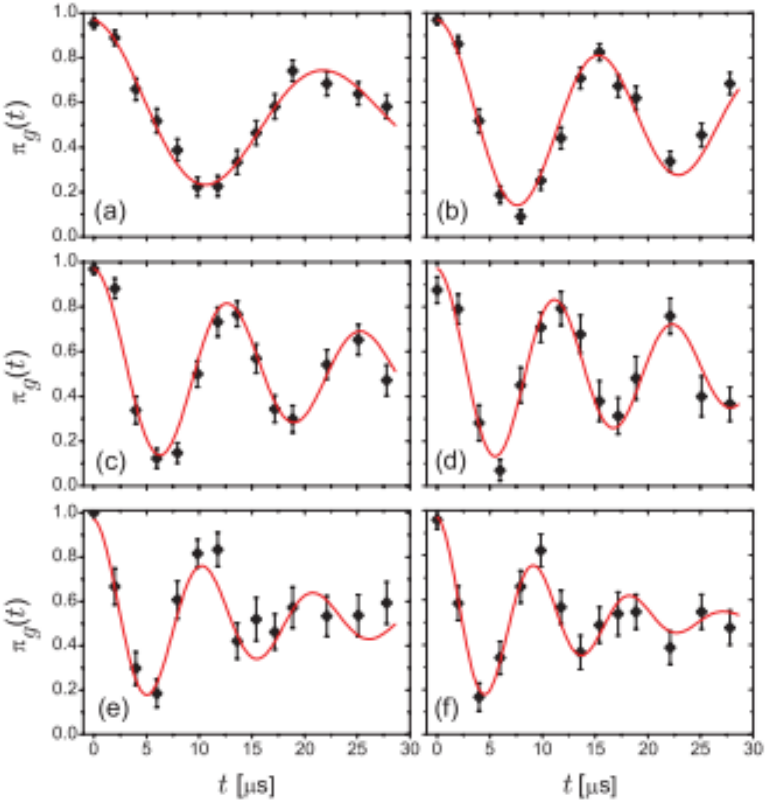
EXPERIMENT



RABI OSCILLATIONS

With initial state $|g,n\rangle$, n=1 to 6.

$$\pi_g^{|g,n\rangle}(t) = \pi_0 + \frac{c}{2} e^{-t/\tau_{n-1}} \cos(\Omega_{n-1} t).$$



RAMSEY

π/2 pulses in R1 and R2.

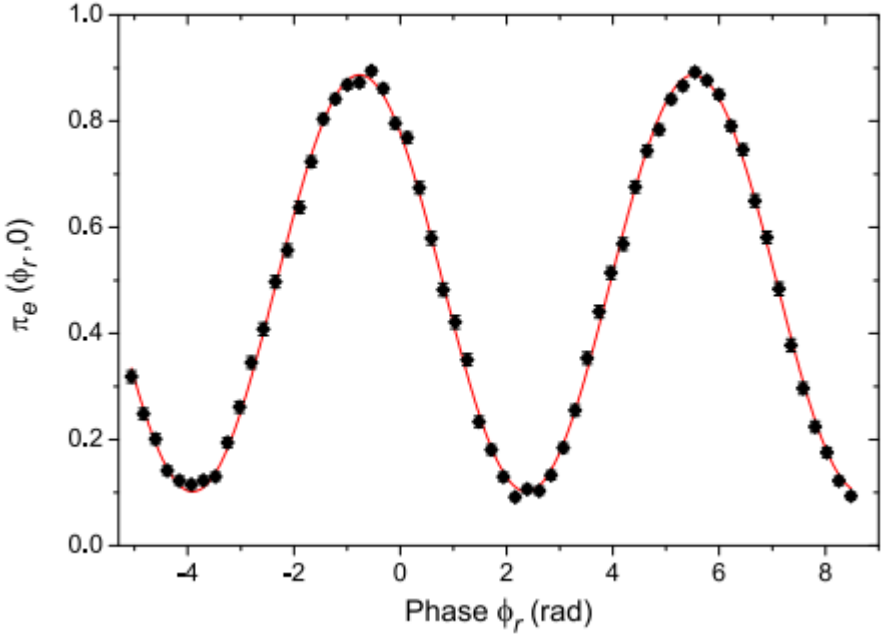
Hamiltonian in dispersive regime:

$$\hat{\mathrm{H}}_{\mathrm{JC}} \cong \frac{\hbar g^2}{\Delta\omega}\hat{\mathrm{a}}_{\mathrm{c}}^{\dagger}\hat{\mathrm{a}}_{\mathrm{c}}(\hat{\sigma}_{\mathrm{ee}} - \hat{\sigma}_{\mathrm{gg}}).$$

Probability π_e of measuring in state $|e\rangle$

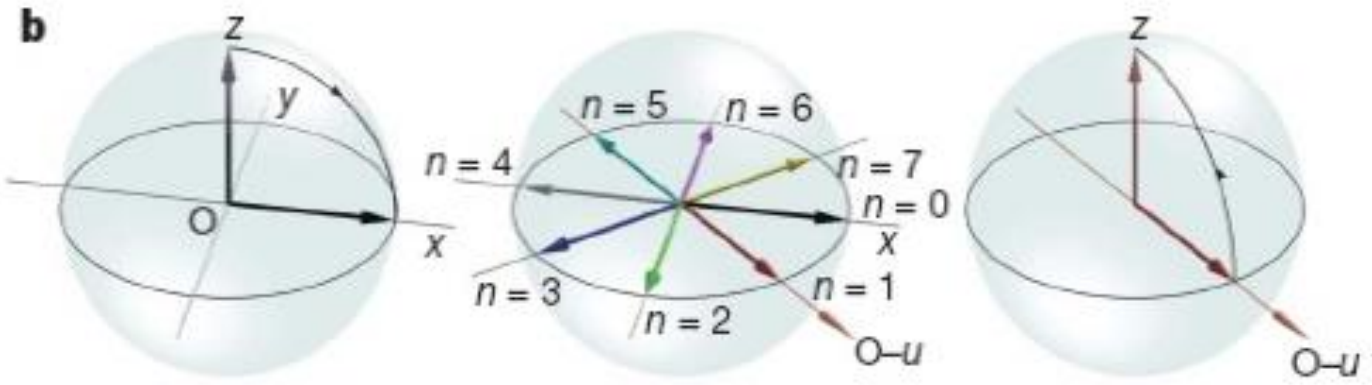
$$\pi_e(\phi_r, n) = \pi_o + \frac{c}{2}\cos\left(\phi_r + \phi_0(n + 1/2)\right)$$

Ramsey pulse phase $\phi_r = (\omega_r - \omega_{eg})T$



RAMSEY (2)

With photons in the cavity

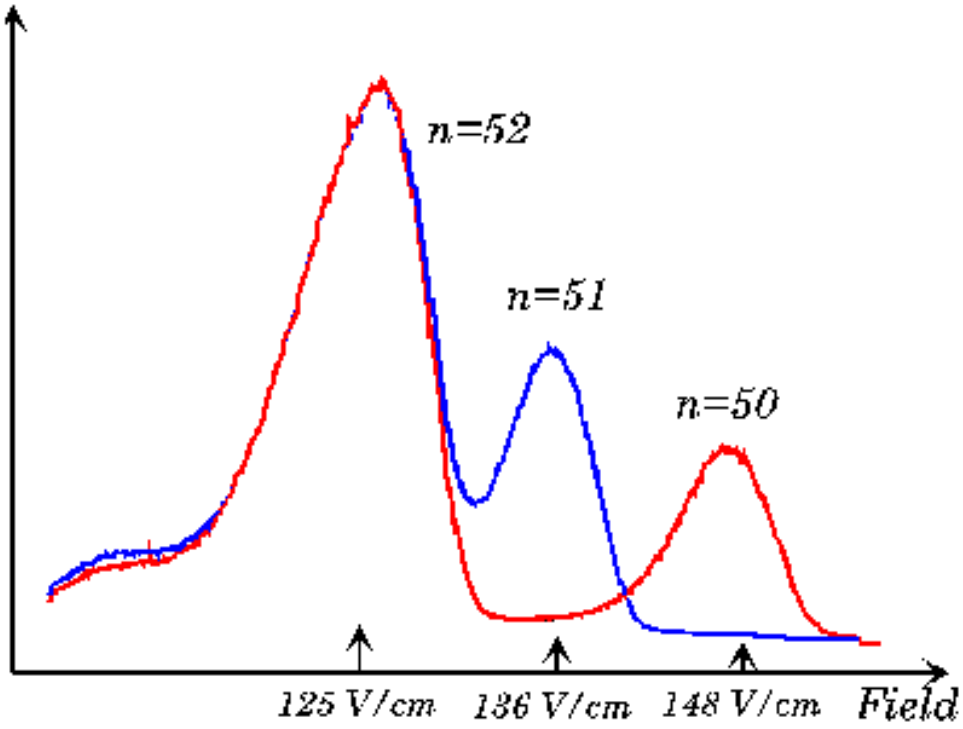


Guerlin et al., Nature (2007)

DETECTOR

Field-ionization detector

Absolute efficiency 0.35



CAVITY

Copper mirrors

Niobium layer

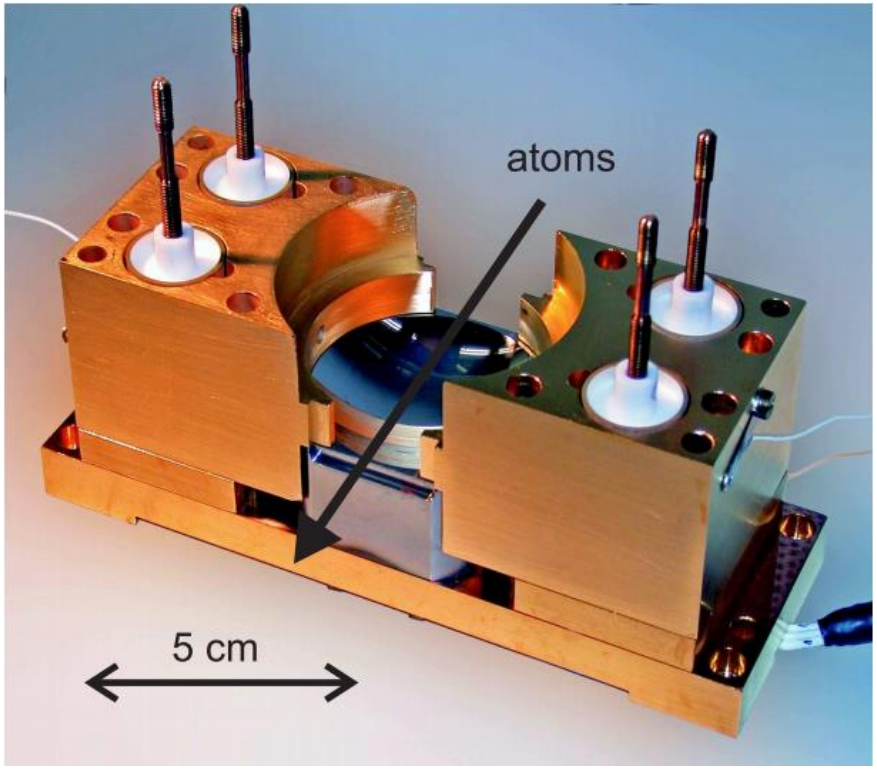
0.8K

Tc = 130ms

Finesse of 4×10^9, highest ever reached in a Fabry-Pérot at any frequency range, $Q=10^{10}$

f = 51GHz

Linewidth ~5Hz !



arXiv:quant-ph/0612138

CONTROLLER

Quantum State Tomography: estimates continuously the maximum likelyhood state density matrix with Bayes Law

Takes into account

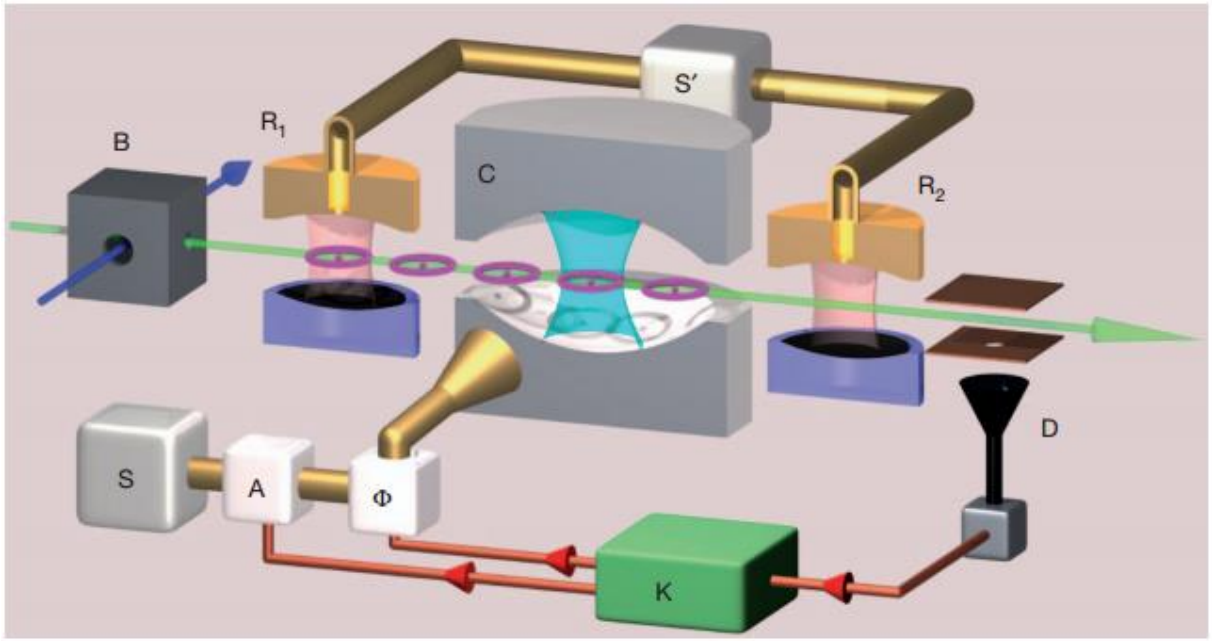
- 0,1,2 Rydberg atoms sent through cavity
- Finite detection efficiency

Calculates a distance $d(\rho_t, \rho)$ between the target state and estimated one and the field to inject in order to minimize it

NATURE

Coherent field injection.

$$d = 1 - \mathrm{Tr}(\Lambda^{(n_t)}\rho)$$

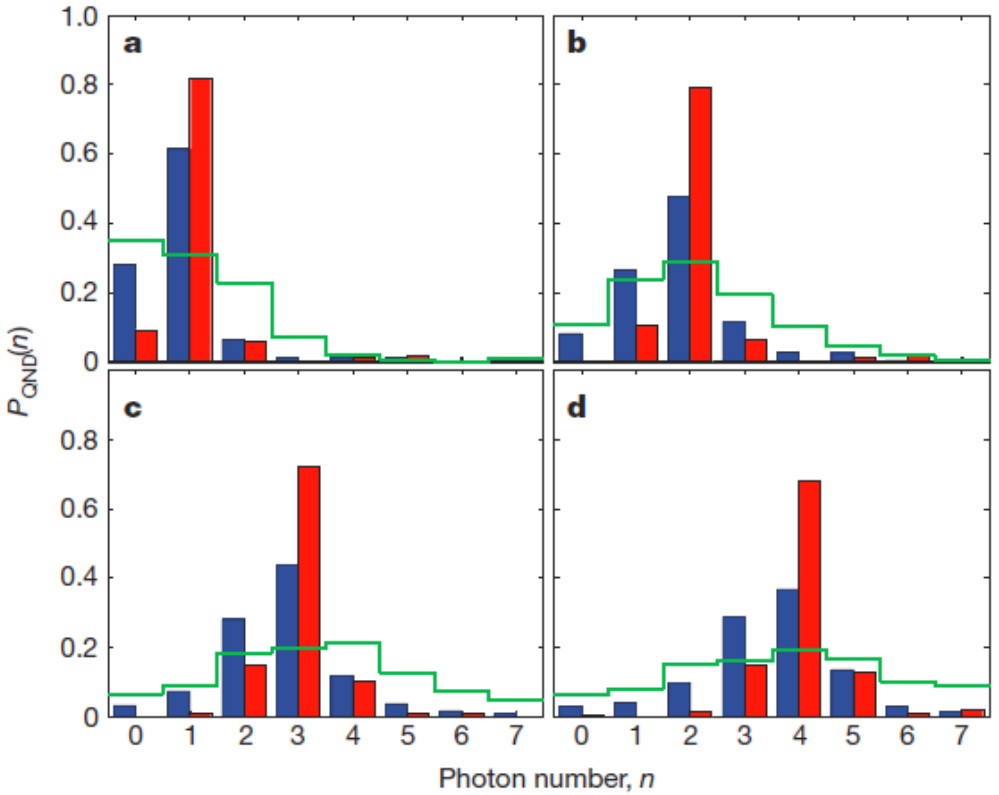


NATURE (2)

Sub-poissonian distribution

Red: after prop > 0.8 estimated

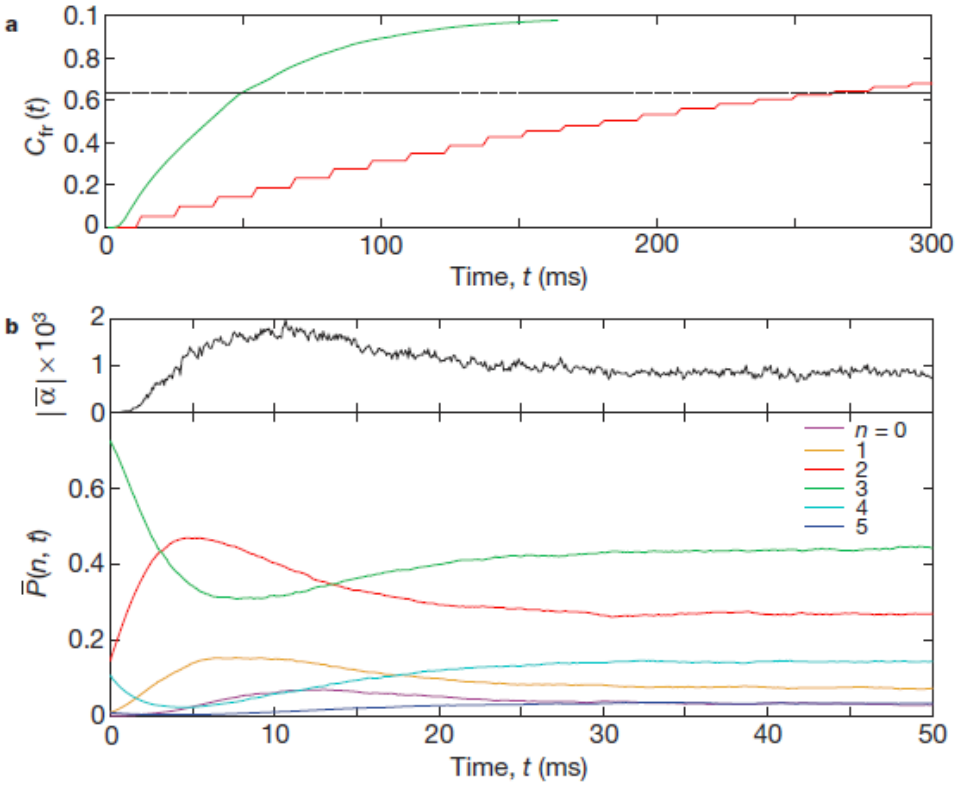
Blue: after fixed time



NATURE (3)

Time to reach objective

Reaction to a quantum jump



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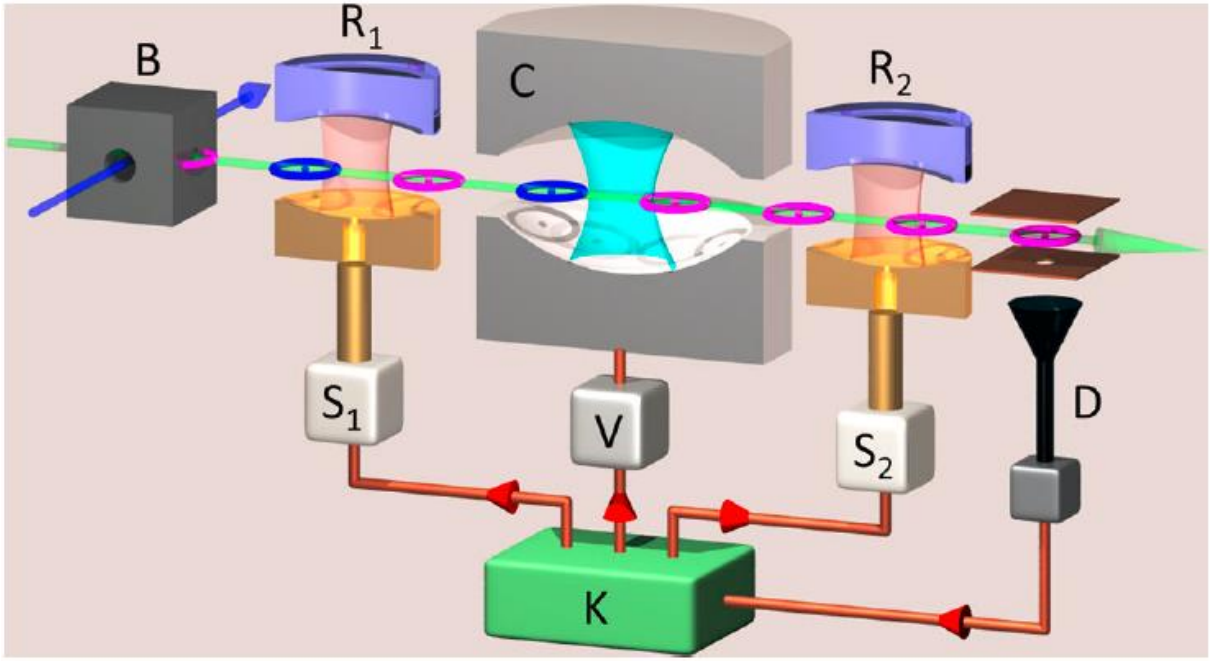
PRL

Dispersive sensors & resonant actuators

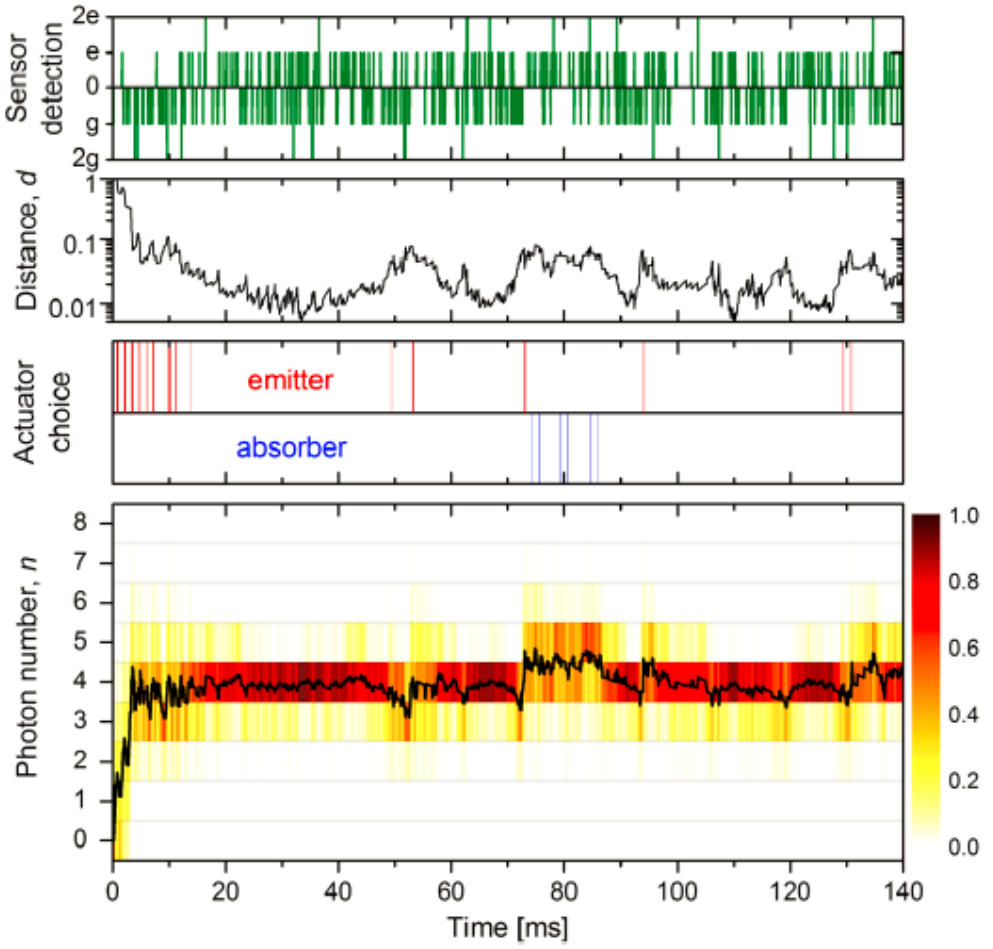
V controls if the Rydberg atom is resonant with the cavity

$$d = \sum_n (n - n_t)^2 p(n)$$

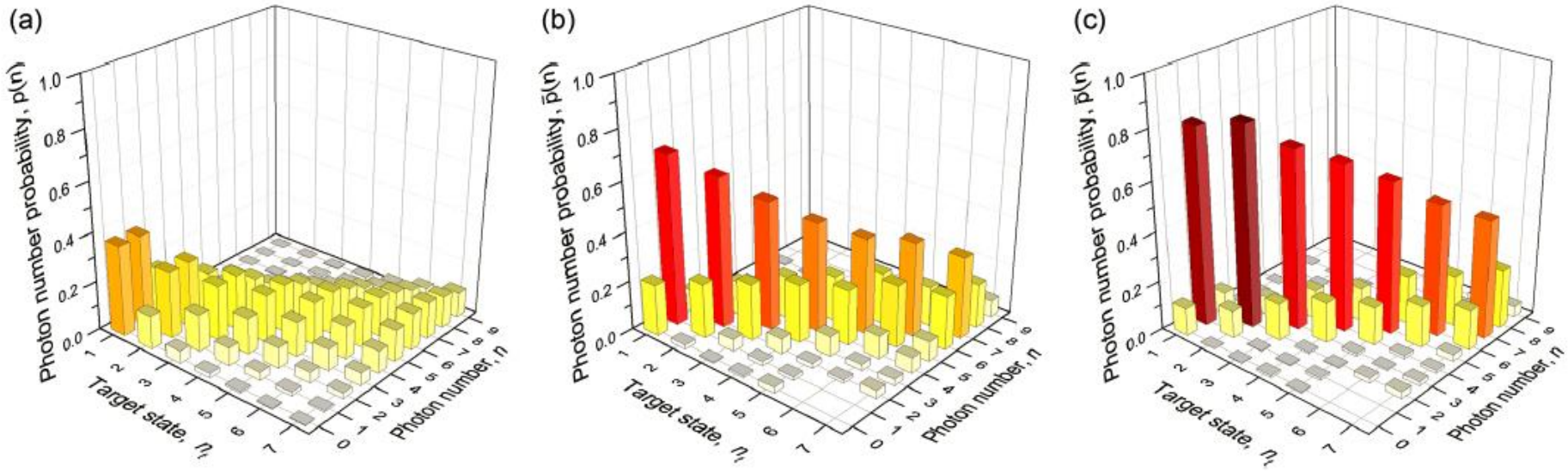


PRL (2)

Example of a experiment aiming at n = 4



PRL (3)



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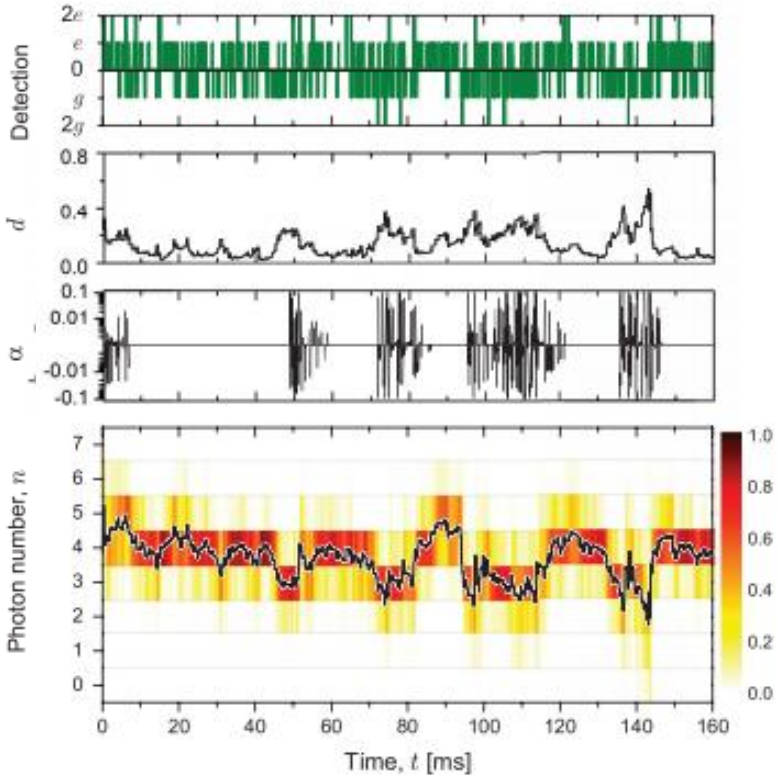
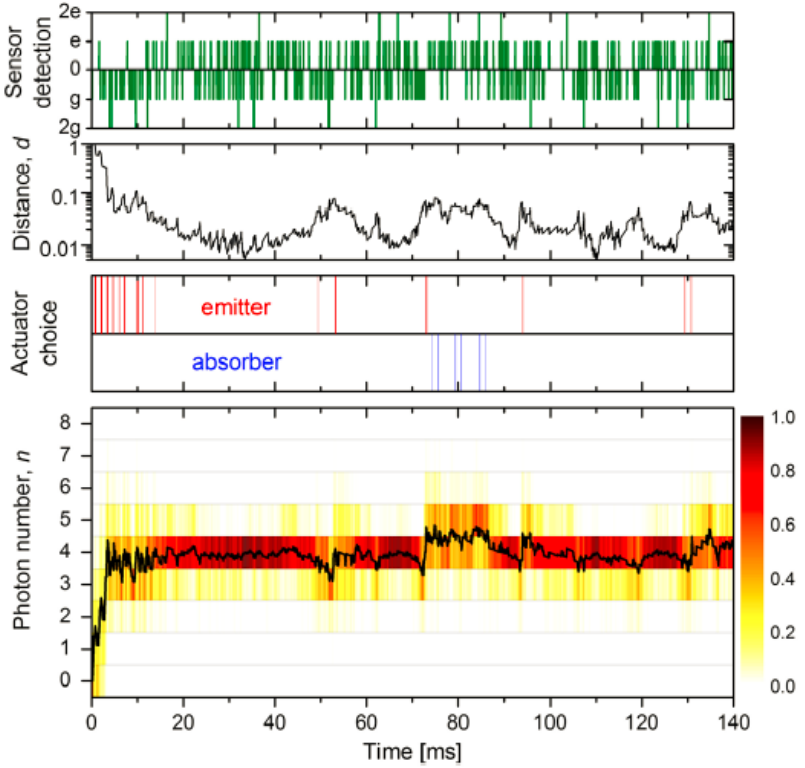
COMPARISON





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OUTLOOK

Protection against decoherence

Programmable trajectory in Hilbert space