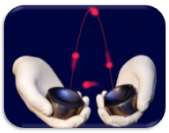


Quantum Electrodynamics of simple systems

Laboratoire Kastler Brossel
Physique quantique et applications

Context of the experiment

Fully controlled manipulation of simple quantum systems

Motivations:

Fundamental understanding of quantum theory
Application to manipulation of quantum information
Control of decoherence

Methods:

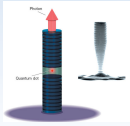
Trap microwave photons in a high Q superconducting cavity
Manipulate the trapped field with single Rydberg atoms

Cavity QED: other experiments

CQED in optics:

Cold atoms in cavities:
- J. Kimble
- G. Rempe
- J. Reichel

…

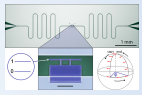


Quantum dots in cavities:
- I. Robert
- JM Gerard
- Y. Yamamoto
- A. Imamoglu …

Circuit QED

- J. Martinis
- R. Schölkopf
- M. Dévoret
- D. Estève
- A. Walraff

…

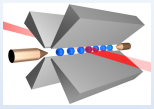


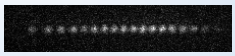
Superconducting qubits coupled to a strip-line cavity

CQED like systems: trapped ions

- D. Wineland
- R. Blatt
- C. Monroe

…

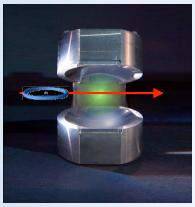




State manipulation by coupling the collective motion with the internal state of ions

Cavity QED in the strong coupling regime

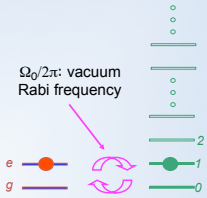
One atom one mode



- 1 atom
- 1 mode
- negligible damping

$T_{cav}, T_{at} >> T_{Rabi} = 2\pi/\Omega_0$

$\Omega_0/2\pi$: vacuum Rabi frequency

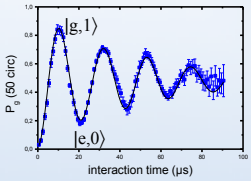


$|e,0\rangle \Leftarrow \Omega_0 \Rightarrow |g,1\rangle$

Vacuum Rabi oscillation

Resonant interaction: observation of vacuum Rabi oscillation:

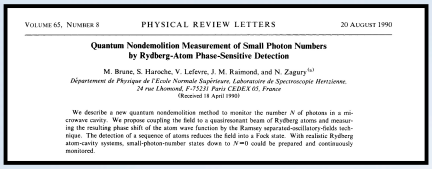
Coherent Rabi oscillation replaces irreversible damping by spontaneous emission



Ω_0=47 kHz
T_{Rabi}=20µs

Brief overview

Proposal: Quantum Non-Demolition measurement

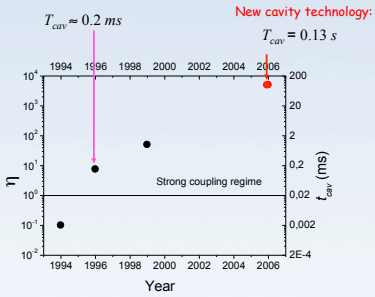


VOLUME 65, NUMBER 8 PHYSICAL REVIEW LETTERS 20 AUGUST 1990

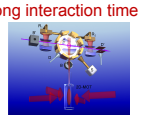
Quantum Nondemolition Measurement of Small Photon Numbers by Rydberg-Atom Phase-Sensitive Detection

M. Brune, S. Haroche, V. Lefevre, J. M. Raimond, and N. Zagury[(a)]
Département de Physique de l'Ecole Normale Supérieure, Laboratoire de Spectroscopie Hertzienne, 24 rue Lhomond, F-75231 Paris CEDEX 05, France
(Received 18 April 1990)

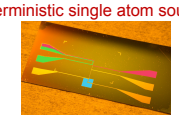
We describe a new quantum nondemolition method to monitor the number N of photons in a microwave cavity. We propose coupling the field to a quasiresonant beam of Rydberg atoms and measuring the resulting phase shift of the atom wave function by the Ramsey separated-oscillatory-fields technique. The detection of a sequence of atoms reduces the field into a Fock state. With realistic Rydberg atom-cavity systems, small-photon-number states down to $N=0$ could be prepared and continuously monitored.



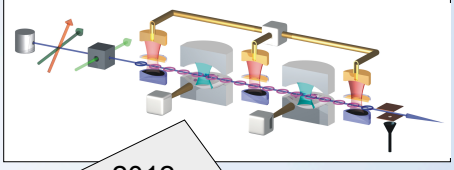
Atomic fountain: Long interaction time



Dipole blockade on atom chip: Deterministic single atom source



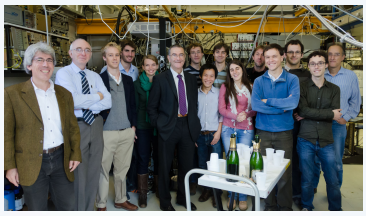
Two cavities: non-local cat state



1990

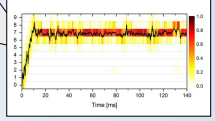
1993

Circular state preparation



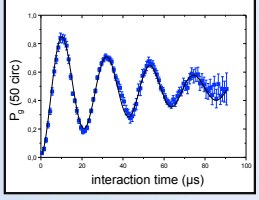
2012 …

Quantum feedback



2011

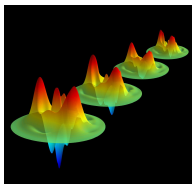
Vacuum Rabi oscillation



1996

2008

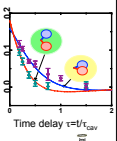
Full quantum state reconstruction



1997 - 2005

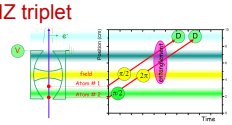
2007

Schrödinger's cat



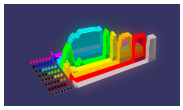
$a_{vif}|\ \rangle + b_{mort}|\ \rangle$

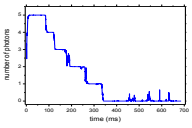
- CNot gate
- EPR Pair preparation
- GHZ triplet



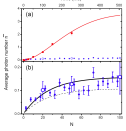
- Two mode entanglement
- Resonant cat state preparation

Quantum jumps of light





Quantum Zeno effect



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