Entanglement of two atoms using the Rydberg Blockade

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When two quantum systems interact strongly, their simultaneous excitation by the same driving pulse may be forbidden: this is called blockade of excitation. Recently, extensive studies have been devoted to the so-called Rydberg blockade between neutral atoms, which appears due to the interaction induced by their large dipole moments when they are in Rydberg states. In particular, this blockade has been proposed as a basic tool in quantum information processing with neutral atoms [1,2] and can be used to deterministically generate entanglement of several atoms.

This talk will describe our demonstration [3] of the Rydberg blockade between two atoms individually trapped in optical tweezers at a distance of 4 micrometers. The rubidium 87 atoms are prepared in the state $|{\uparrow}\rangle = |F=2, M=2\rangle$, and subsequently excited to the Rydberg state $58d_{3/2}$, $|r\rangle$, by a two-photon transition. In the blockade regime, two atoms cannot be excited at the same time.

A consequence of this blockade mechanism is that the atoms are excited in an entangled state of the form $(|r,{\uparrow}\rangle + e^{i\phi}|{\uparrow},r\rangle)/\sqrt{2}$, where ϕ is a phase depending on the position of the atoms. The signature of the production of this state is the enhanced Rabi frequency of the oscillation of the probability to excite only one of the two atoms, with respect to the Rabi frequency of the excitation of one atom when it is alone. The talk will detail this experimental demonstration.

The entangled state produced in this way has a short lifetime, due to the fact that the atoms are not trapped while in the Rydberg state. We have then mapped the Rydberg state $|r\rangle$ onto a second ground state $|{\downarrow}\rangle = |F=1, M=1\rangle$ to generate the Bell state $(|{\downarrow},{\uparrow}\rangle + |{\uparrow},{\downarrow}\rangle)/\sqrt{2}$. We analyse the amount of entanglement by global Raman rotations on the two atoms. We have found a fidelity of the two-atom state produced of 0.75. This confirms the quantum nature of the correlations produced [4].

[1] D. Jaksch, *et al.*, « Fast quantum gates for neutral atoms », Phys. Rev. Lett. **85**, 2208 (2000).

[2] M. D. Lukin, *et al.*, « Dipole blockade and quantum information processing in mesoscopic atomic ensembles », Phys. Rev. Lett. **87**, 037901 (2001).

[3] A. Gaëtan, *et al.,* « Observation of collective excitation of two individual atoms in the Rydberg blockade régime », Nature Physics **5**, 115 (2009).

[4] T. Wilk, *et al.*, "Entanglement of two individual neutral atoms using Rydberg blockade", arXiv:0908.0454.