Q 2: Quanteninformation: Atome und Ionen I

Zeit: Montag 10:45–12:15 Raum: ESA-B

Q 2.1 Mo 10:45 ESA-B

Optimierte Initialisierung eines ^{171}Yb$^+$-Ions in den Zustand ^{2}S$_{1/2}$,F=0 — •Ingo Baumgart, Nuala Timoney und Christof Wunderlich — Fachbereich Physik, Universität Siegen,Walter-Flex-Straße 3, 57072 Siegen

Schnelle und effektive Initialisierung eines Anfangszustandes ist im Hinblick auf die Realisierung eines Quantenrechners oder für Quanten-Simulation eine wichtige Voraussetzung.

Die als quantenmechanisches Zwei-Niveau-System genutzten Hyperfeinstruktur-Zustände $^2S_{1/2}, F = 0$ und $^2S_{1/2}, F = 1, m_F = 0$ eines in einer Paul-Falle gespeicherten ^{171}Yb$^+$-Ions können durch ein resonantes Mikrowellenfeld bei einer Frequenz von 12,6 GHz kohärent manipuliert werden. Zum Dopplerkühlen des Ions wird auf den Übergang $^2S_{1/2}, F = 1 \leftrightarrow {}^2P_{1/2}, F = 0$ Licht bei 369 nm eingestrahlt. Um für die Zustandspräparation den Übergang $^2S_{1/2}, F = 1 \leftrightarrow {}^2P_{1/2}, F = 1$, mit dem anschließenden Zerfall in den Zustand $^2S_{1/2}, F = 0$ resonant anzuregen, wird das Licht bei 369 nm um 2,1 GHz mit einem Sechsfach-Durchgang durch einen akustooptischen Modulator zu größeren Frequenzen hin verstimmt.

Im Vergleich zur bisherigen Methode wird so eine wesentliche Verbesserung der Präparationseffizienz erreicht. Dafür wird eine minimale Lichtleistung von 0,02 W/(mm)^2 im Fallenzentrum benötigt und eine kürzere Präparationszeit von bisher minimal 25 μs erzielt. Die so erlangte Präparationseffizienz von annähernd 100 % stimmt gut mit den durchgeführten Simulationen überein.

Q 2.2 Mo 11:00 ESA-B

Single-photon spectroscopy on a single ion — •Carsten Schuck, Nicolas Piro, Felix Rohde, Marc Almendros, Jan Huwer, Morgan W. Mitchell, Markus Hennrich, Francois Dubin, Albrecht Haase, and Jürgen Eschner — ICFO - The Institute of Photonic Sciences, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain

The realization of a quantum network requires the distribution of entanglement between its nodes. For some of the most promising implementations this requires the interaction of single atoms with single photons. Here we investigate the interaction of a single calcium ion with heralded single photons generated by a spontaneous parametric down-conversion source whose emission is tailored to coincide with the 20MHz bandwidth of the atomic resonance [1]. We focus these photons onto the atom with a high numerical aperture lens and monitor the rate of fluorescence photons continuously emitted by the laser-cooled ion. On absorption of a photon from the pair-source the ion may subsequently decay to a metastable state outside the cooling cycle, i.e. we observe a quantum jump in the fluorescence rate. We perform single-photon spectroscopy of a single atom by measuring the rate of these quantum jumps as a function of the photon pair generation rate and the detuning of the down conversion source from the atomic transition. In both cases we observe clear evidence for the interaction between heralded down-conversion photons and a single trapped ion.

[1] A. Haase et al., Opt. Lett. in print (arXiv:0808.1988)

Q 2.3 Mo 11:15 ESA-B

High fidelity entanglement of ^{43}Ca$^+$ hyperfine clock states — •Gerhard Kirchmair[1,2], Rene Gerritsma[1,2], Florian Zähringer[1,2], Jan Benhelm[1,2], Christian Roos[1,2], and Rainer Blatt[1,2] — [1]Institut für Experimentalphysik, Universität Innsbruck, Technikerstr. 25, A-6020 Innsbruck, Austria — [2]Institut für Quantenoptik und Quanteninformation, Österreichische Akademie der Wissenschaften, Otto-Hittmair-Platz 1, A-6020 Innsbruck, Austria

In an experiment using the odd calcium isotope ^{43}Ca$^+$ we combine the merits of a high fidelity entangling operation on an optical transition (optical qubit) with the long coherence times offered by two "clock"states in the hyperfine ground state (hyperfine qubit) by mapping between these two qubits. We achieve state initialization, state detection, global qubit rotations and mapping operations with errors smaller than 1%, whereas the Mølmer-Sørensen entangling gate adds errors of 2.3%. We create Bell states with a fidelity of 96.9(3)% in the optical qubit and a fidelity of 96.7(3)% when mapped to the hyperfine states. In the latter case the entanglement is preserved for 96(3) ms, exceeding the gate duration by three orders of magnitude. The Bell state stored in the hyperfine qubit can be mapped back to the optical qubit and additional gate operations disentangle/entangle the ions again. In addition we present results on entangling three ^{40}Ca$^+$ ions in a GHZ state with a fidelity of 98%.

Q 2.4 Mo 11:30 ESA-B

Photon-Photon Entanglement with an Atom-Cavity System — •Martin Mücke, Bernhard Weber, Holger Specht, Tobias Müller, Joerg Bochmann, David Moehring, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

We report on the implementation of a deterministic protocol where a single rubidium atom trapped within a high-finesse optical cavity is entangled with an emitted photon [1]. After a chosen time, the atomic state is mapped onto a second photon, thus generating an entangled photon pair. Compared to previous experiments with falling atoms [2], the long trapping times of exactly one atom in the mode of the cavity allow for $\sim 10^5$ times more entangled photons per atom and also for a measurement of the coherence time of the atomic qubit. The entanglement is verified by a Bell inequality measurement that is in clear violation of classical physics. Furthermore, the two-photon state is characterized via quantum state tomography.

[1] B. Weber *et al.*, accepted by PRL, arXiv:0811.3612v1
[2] T. Wilk *et al.*, Science **317**, 488 (2007)

Q 2.5 Mo 11:45 ESA-B

Electromagnetically induced transparency involving Rydberg states in a rubidium microcell — •Harald Kübler[1], James Shaffer[2], Alex Charnukha[1], Thomas Baluktsian[1], Christian Urban[1], Robert Löw[1], and Tilman Pfau[1] — [1]5. Physikalisches Institut, Universität Stuttgart, Germany — [2]Homer L. Dodge Department Of Physics And Astronomy, University of Oklahoma, USA

Small glass cells filled with rubidium vapor are promising candidates for quantum information processing using Rydberg states. Due to the strong interaction between two Rydberg atoms, only one Rydberg excitation is possible within a certain volume characterized by the blockade radius (typically few microns), that is determined by the laser bandwidth and the interaction strength. This effect called "dipole blockade", provides a nonlinearity that is an essential tool for proposals to entangle atoms using Rydberg states. Similarly, atomic vapor confined on a length scale comparable to the blockade radius can be used like quantum wells (2D), quantum wires (1D) and quantum dots (0D) e.g. to realize a single photon source. We present measurements in rubidium vapor cells with thicknesses on the order of the blockade radius. We observed EIT with Rydberg states and investigated the effects of the confinement in these vapor cells. These experiments show that coherent dynamics involving Rydberg states are possible in micro cells above room temperature.

Q 2.6 Mo 12:00 ESA-B

Towards entanglement of two individual atoms using the Rydberg blockade — •Tatjana Wilk, Alpha Gaëtan, Yevhen Miroshnychenko, Charles Evellin, Antoine Browaeys, and Philippe Grangier — Laboratoire Charles Fabry, Institut d'Optique, Palaiseau, France

The Rydberg blockade is of great interest for many quantum information processing schemes, since it provides a way to deterministically entangle two or more atoms and to drive fast quantum gates [1]. First experimental efforts into this direction recently succeeded in the observation of the Rydberg blockade between two ^{87}Rb atoms individually trapped in two neighboring dipole traps [2,3]. Furthermore, in the two atom system the Rabi frequency for oscillations between the ground state $|gg\rangle$ and *one* atom in the Rydberg state is enhanced by $\sqrt{2}$ with respect to the Rabi frequency for a single atom [3]. This indicates the production of an entangled state $(|gr\rangle + |rg\rangle)/\sqrt{2}$. To be able to quantify the entanglement between the two atoms in a Bell test or a state tomography, the Rydberg state is mapped onto another ground state $|g'\rangle$. Rotations of the measurement basis are done with a pair of Raman lasers coupling $|g\rangle$ and $|g'\rangle$. The atomic state is read out observing the fluorescence of the remaining atoms after ejecting atoms in state $|g\rangle$ from the trap. We report on the current status of the experiment. [1] D. Jaksch et al., *Phys. Rev. Lett.* **85**, 2208 (2000). M.D. Lukin et al., *Phys. Rev. Lett.* **87**, 037901 (2001). [2] E. Urban et

al., *arxiv:0805.0758.* [3] A. Gaëtan et al., *Nature Phys.* (accepted, see also *arxiv:0810.2960*).