Q 11: Quantum Information: Atoms and Ions 1

Time: Monday 14:30–16:00 Location: BAR Schön

Q 11.1 Mon 14:30 BAR Schön

Remote Entanglement between a Single Atom and a Bose-Einstein Condensate — •Matthias Lettner, Martin Mücke, Stefan Riedl, Christoph Vo, Carolin Hahn, Simon Baur, Jörg Bochmann, Stephan Ritter, Stephan Dürr, and Gerhard Rempe — Max Planck-Institut für Quantenoptik, Hans Kopfermann Str.1, 85748 Garching

Entanglement has been recognised as a puzzling yet central element of quantum physics with applications envisioned in many fields like quantum computing and quantum networking. In the latter field photons will act as flying qubits for the entanglement of remote atomic systems. Here we report on the experimental demonstration of entanglement between a single atom located inside a high-finesse optical cavity and a Bose-Einstein condensate (BEC). To this end we generate a single photon in the atom-cavity system, entangling the photon polarisation with the atomic spin state. The photon is transported to a different laboratory, where it is stored in a BEC employing electromagnetically induced transparency (EIT). This converts the atom-photon entanglement into remote matter-matter entanglement. Subsequently we map the matter-matter entanglement onto photon-photon entanglement. The resulting two-photon state is found to have high fidelity with a maximally-entangled Bell state proving that entanglement survives all described mapping procedures. We determine the lifetime of the remote matter-matter entanglement and discuss decoherence mechanisms.

Q 11.2 Mon 15:00 BAR Schön

Single atom-photon interfaces with strongly focused optical modes — •Gleb Maslennikov[1], Syed Abdullah Aljunid[1], Jian-Wei Lee[1], Martin Paesold[2], Dao Hoang Lan[1], Kadir Durak[1], Brenda Chng[1], and Christian Kurtsiefer[1] — [1]Centre for Quantum Technologies / Dept. of Physics, National University of Singapore — [2]ETH, Zurich

Interaction of light with single atoms forms the basic building block in many scenarios for the exchange of quantum information between different physical carriers, for the implementation of simple quantum logic devices, and for a better understanding of localizable single photon states. Complementary to the well-known approach of optical field enhancement with cavities we investigate field enhancement due to strong focusing of an optical mode. With this, we have seen significant extinction, optical phase shifts, which eventually should allow for significant interaction between photons [1-3]. We discuss our experimental progress on atom localization, atomic excitation probabilities under weak optical pulses and an anaclastic cavity-lens geometry for optical field enhancement at the atom with a very high optical coupling between probing and detection modes.

[1] M. K. Tey, et al., Nature Physics **4** 924 (2008)
[2] S.A. Aljunid et al., Phys. Rev. Lett. **103**, 153601 (2009)
[3] S.A. Aljunid et al., arXiv:1006.2191 (2010)

Q 11.3 Mon 15:15 BAR Schön

Entanglement-preserving absorption of single photons by a single atom — •Michael Schug[2], Jan Huwer[1,2], Joyee Ghosh[1,2], Nicolas Piro[1], Marc Almendros[1], Felix Rohde[1], Carsten Schuck[1], Francois Dubin[1], and Jürgen Eschner[1,2] — [1]ICFO - Institut de Ciences Fotoniques, Mediterranean Technology Park, 08860 Castelldefels (Barcelona), Spain — [2]Universität des Saarlandes, Experimentalphysik, Campus E2.6, 66123 Saarbrücken

We observe the absorption of single down-conversion photons by a single $^{40}Ca^{+}$ ion, heralded by the detection of the partner photons. A photon absorption event induces a quantum jump in the ion, detected as a sudden change in its fluorescence rate. The correlation function of the quantum jumps and the arrival times of the partner photons reveals the coincidence between the two events [1]. Additionally, we observe that the polarization entanglement of the photons is preserved in the absoprtion process. This shows the potential of the method as a tool in quantum optical information technology.

[1] N.Piro et al., DOI: 10.1038/NPHYS1805

Q 11.4 Mon 15:30 BAR Schön

Entanglement Distribution with an Atom-Cavity-System — •Carolin Hahn, Martin Mücke, Jörg Bochmann, Andreas Neuzner, Stephan Ritter, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

The deterministic generation and distribution of entanglement is one of the key ingredients for applications in quantum information science. In our system, a single Rubidium atom is quasi-permanently trapped inside a high-finesse optical cavity. Using this atom and a suitable energy-level scheme to produce a single photon entangles the polarization state of the emitted photon with the Zeeman-state of the atom. After a chosen time $\Delta\tau$, the atomic state is mapped onto the polarization of a second photon, thus generating a maximally entangled photon pair. Technical improvements have increased the entanglement lifetime of our Zeeman qubit by more than one order of magnitude, now exceeding $\Delta\tau = 150\mu s$. So far, these experiments have been studied on the ^{87}Rb D_2-line at 780 nm. However, the prospect of interfacing our system e.g. with atomic systems, poses a strong incentive to implement a similar scheme on the D_1-line at 795 nm. In addition, the involved excited state provides a much cleaner level scheme and therefore allows for higher fidelities with the desired entangled state. We report on the extension of the protocol to the D_1-line. A detailed comparison of the system's performance with respect to fidelity and photon generation efficiency at the two different wavelengths will be given and future applications will be discussed.

Q 11.5 Mon 15:45 BAR Schön

Entangling two single atoms at remote locations — •Julian Hofmann[1], Norbert Ortegel[1], Michael Krug[1], Florian Henkel[1], Wenjamin Rosenfeld[1,2], Markus Weber[1], and Harald Weinfurter[1,2] — [1]Department für Physik der LMU, München — [2]Max-Planck Institut für Quantenoptik, Garching

Entanglement between distant atomic quantum memories is a key resource for future applications in quantum communication. Here we present our recent progress on establishing entanglement between two single Rb-87 atoms over a large distance.

For this purpose we have set up two independently operating atomic traps situated in two neighboring laboratories separated by 20 meter. On each side we capture a single neutral Rb-87 atom in an optical dipole trap and generate a spin-entangled state [1] between the atom and a photon. The emitted photons are collected with high-NA objectives into single-mode optical fibers and guided to the same 50-50 fiber beam-splitter where we observe their interference. This setup allows us to detect two of four maximally entangled Bell states, thereby projecting the two atoms into an entangled state.

Here we report the progress towards the verification of the entanglement between the two distant atoms.

[1] J. Volz, et al. Phys. Rev. Lett. 96, 030404 (2006).