Q 19: Quantum Information (Quantum Repeater) I

Time: Monday 16:15–17:45 Location: S HS 001 Chemie

Q 19.1 Mon 16:15 S HS 001 Chemie

Atom-to-photon quantum state mapping into the telecom range — •Stephan Kucera, Matthias Bock, Pascal Eich, Christoph Becher, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken

Quantum interfaces between atomic nodes and photonic quantum channels are essential building blocks for single-atom based quantum networks. In previous work, we demonstrated photon-to-atom quantum state transfer from a polarization qubit at 854 nm onto the spin qubit of a single trapped $^{40}Ca^{+}$ ion and atom-to-photon quantum state mapping onto a single 393 nm photon [1,2]. Here, we extend the latter atom-to-photon interface to near IR wavelength at 854 nm, and connect it to the low-loss telecom O-band at 1310 nm via state-of-the-art high-fidelity quantum frequency conversion [3].

[1] C. Kurz et al., Nat. Commun. **5**, 5527 (2014)
[2] C. Kurz et al., Phys. Rev. A **93**, 062348 (2016)
[3] M. Bock et al., Nat. Commun. **9**, 1998 (2018)

Q 19.2 Mon 16:30 S HS 001 Chemie

Quantum network routing and local complementation — •Frederik Hahn[1], Anna Pappa[2], and Jens Eisert[1] — [1]Freie Universität Berlin, Berlin, Deutschland — [2]University College London, London, Großbritannien

Quantum communication between distant parties is based on suitable instances of shared entanglement. For efficiency reasons, in an anticipated quantum network beyond point-to-point communication, it is preferable that many parties can communicate simultaneously over the underlying infrastructure; however, bottlenecks in the network may cause delays. Sharing of multi-partite entangled states between parties offers a solution, allowing for parallel communication. Specifically for the two-pair problem, the butterfly network provides the first instance of such an advantage in a bottleneck scenario. The underlying method differs from standard repeater network approaches in that it uses a graph state instead of maximally entangled pairs to achieve long-distance simultaneous communication. We show how graph theoretic tools, and specifically local complementation, help decrease the number of required measurements compared to usual methods applied in repeater schemes. We consider other examples of network architectures, where deploying local complementation techniques provides an advantage. (The talk is based on arXiv:1805.04559v2)

Q 19.3 Mon 16:45 S HS 001 Chemie

Optical Quantum Information Processing with Atom-Filled Hollow-Core Photonic Crystal Fibres — •Ben Sparkes, Jed Rowland, Christoper Perrella, Jonathan Hedger, Ashby Hilton, Philip Light, and Andre Luiten — Institute for Photonics and Advanced Sensing, School of Physical Sciences, University of Adelaide, Adelaide, SA 5005 Australia

Quantum information networks will deliver the capability for long-distance, provably-secure communications via quantum key distribution, as well as optical quantum computing. Our work aims to provide components for these quantum networks: our specific design makes use of hollow-core photonic crystal fibres (HCPCFs) filled with rubidium atoms, and are amenable to direct integration with current optical fibre technology. The tight transverse confinement (diameter of tens of microns) and extended interaction lengths (centimetres) of the HCPCFs provides an extremely optically dense medium, ideal for efficient quantum information storage and for achieving strong atom-mediated photon-photon interactions.

We will present results showing the efficient, coherent and noiseless storage of high-bandwidth optical pulses in warm rubidium-filled HCPCFs using the off-resonance cascade absorption (ORCA) technique. We have also recently demonstrated the ability to load a record number of laser-cooled atoms into a hollow-core optical fibre and will present our latest results towards achieving high efficiency storage with coherence times of up to milliseconds using the highly-efficient Gradient Echo Memory (GEM) technique.

Q 19.4 Mon 17:00 S HS 001 Chemie

Efficient single-photon collection for long-distance entanglement of atoms — •Robert Garthoff[1], Tim van Leent[1], Kai Redeker[1], Paul Koschmieder[1], Wei Zhang[1], Wenjamin Rosenfeld[1,2], and Harald Weinfurter[1,2] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [2]Max-Planck-Institut für Quantenoptik, Garching, Germany

Entanglement between distributed quantum systems forms the basis of future quantum networks and thus will be essential for secure quantum communication and distributed quantum computing. The only suitable candidate to interconnect separate quantum memories are photons. Currently, efficient collection of photons from the quantum memory limits the generation of remote entanglement in schemes based on entanglement swapping.

Here we present the experimental details and results of the optimization of the photon collection efficiency from a single trapped Rb-87 atom used as a quantum memory. Using custom designed microscope objectives with a high numerical aperture and corrected for our specific experimental geometry, we expect at least a threefold increase of the collection efficiency and thereby an improvement of remote entanglement rate by one order of magnitude relative to that achieved in our previous measurements[1].

[1] W. Rosenfeld, Phys. Rev. Lett. **119**, 010402 (2017).

Q 19.5 Mon 17:15 S HS 001 Chemie

A multiplexed individual-atom memory for photonic qubits — •Stefan Langenfeld, Matthias Körber, Olivier Morin, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Strasse 1, 85748 Garching, Germany

Quantum memories can preserve qubits for an extended duration. In combination with the capability to map photonic qubits into and out of the memory, this has important applications in quantum computation and communication. After recently demonstrating a qubit memory featuring a coherence time compatible with global scale communication [1], we now implement multi-qubit storage capabilities in the same setup. Our system consists of several ^{87}Rb atoms trapped in a two-dimensional optical lattice in a high-finesse optical resonator. We use an imaging system capable of resolving the position of individual atoms [2]. An acousto-optic deflector enables to select any atom and steer an optical beam onto it which we use for an atom-selective single-photon stimulated Raman adiabatic passage (STIRAP). Decoupling of the unaddressed atoms and the cavity by using single-photon detunings of many MHz results in close to negligible cross-talk and near-unity fidelity. These results promote individually addressable neutral atoms in optical cavities to a scalable architecture and make them a prime candidate for realizing quantum repeater architectures.

[1] M. Körber, O. Morin et al., Nat. Photonics 12, 18-21 (2018)
[2] A. Neuzner et al., Nat. Photonics 10, 303-306 (2016)

Q 19.6 Mon 17:30 S HS 001 Chemie

Atom-to-photon state mapping by quantum teleportation — •Jan Arensktter[1], Stephan Kucera[1], Matthias Kreis[1], Floriane Brunel[2], Pascal Eich[1], Philipp Müller[1], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Experimentalphysik, Campus E2.6, 66123 Saarbrücken — [2]Université Côte d'Azur, 06108 Nice, France

Atom-to-photon quantum teleportation is an alternative to direct transmission of quantum bits. We demonstrate the teleportation of a qubit encoded in the $D_{5/2}$ Zeeman sub-levels of a $^{40}Ca^{+}$ ion onto the polarization qubit of a single 854 nm photon by heralded absorption [1] of the other photon of an SPDC pair. This method allows us to measure two out of four Bell states. Here we present an extension to full Bell state detection by back-reflection of non-absorbed photons. We verify the method by photon-to-atom quantum state transfer using laser photons.

[1] C. Kurz et al., Nat. Commun. **5**, 5527 (2014)