Q 31: Quantum Communication IV

Time: Wednesday 11:00–13:00 Location: HS 3219

Q 31.1 Wed 11:00 HS 3219

Free-Space Quantum Key Distribution at Daylight using the Sodium D_2 Line — •Ilija Funk, Yagana Syed, and Ilja Gerhardt — Leibniz University Hannover, light & matter group, Appelstrasse 2, 30167 Hannover

Quantum key distribution is a promising pathway to secure communication in the future. Currently, quantum communication channels usually are realized through a fiber or a free-space network. While the latter offers much longer transmission distances of hundreds of kilometers compared to fiber links, it suffers from reduced transmission rates during daytime due to increased detection noise from sunlight. To circumvent this problem, we propose a free-space link based on entangled photon pairs with a wavelength of 589 nm. This wavelength coincides with the sodium D_2 line which is one of the most prominent Fraunhofer lines. Hence during daytime, the reduced amount of sunlight at this wavelength should allow for an improved transmission rate. Our research project includes the creation of entangled photon pairs at 589 nm, setting up a free-space link over several kilometers using telescopes, and demonstrating quantum key distribution using the BBM92 protocol. We report on our latest progress.

Q 31.2 Wed 11:15 HS 3219

A scalable quantum register for multiplexed atom-photon entanglement — •Lukas Hartung[1], Matthias Seubert[1], Stephan Welte[2], Emanuele Distante[1], and Gerhard Rempe[1] — [1]Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching — [2]ETH Zürich, Otto-Stern-Weg 1, 8093 Zürich

Trapped atoms in the centre of a cavity have been used for the efficient generation of atom-photon entanglement[1]. However, in past experiments the number of atoms in the resonator was limited to at most two[2], as the loading of individual atoms was based on probabilistic schemes. To overcome this limitation, we have extended our setup with an addressing system that allows to load presently up to six atoms into the cavity using optical tweezers. Additionally, the system enables individual addressing of the atoms to generate atom-photon entangled pairs via a vaccum STIRAP[3]. We show that the fidelity of this entanglement process is independent of the number and spatial arrangement of the atoms, which is an indicator of the scalability of our system. Finally, we use the setup to generate atom-photon entanglement in a multiplexed way with an efficiency of up to 88.6(1)%.

[1] Philip Thomas et al., Efficient generation of entangled multiphoton graph states from a single atom. Nature 608, 677-681 (2022).

[2] Stephan Welte et al., Photon-Mediated Quantum Gate between Two Neutral Atoms in an Optical Cavity, Phys. Rev. X 8, 011-018 (2018).

[3] Tatjana Wilk et al., Single-Atom Single-Photon Quantum Interface. Science 317, 488-490 (2007).

Q 31.3 Wed 11:30 HS 3219

Towards time-energy entanglement swapping of asynchronous sources — •Karen Lozano-Mendez[1,2], Markus Leipe[1,2], Sakshi Sharma[1,2], Meritxell Cabrejo Ponce[1,2], and Fabian Steinlechner[1,2] — [1]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, 07745 Jena, Germany — [2]Friedrich Schiller University Jena, Institute of Applied Physics, Abbe Center of Photonics, Albert-Einstein-Str. 15, 07745 Jena, Germany

Time-energy entanglement in photons is a robust choice for fiber-based quantum communications. Entanglement can be 'swapped' if two independent entangled photons pairs are prepared and a Bell state measurement is made between two photons, one from each source. This will project the two remaining, non-interacting photons in an entangled state. Entanglement swapping has been successfully executed using synchronized, pulse-pumped sources. However, only a few realizations using a continuous wave pump have been reported.

We use entangled photon pairs generated independently via SPDC from two integrated ppLN waveguides, which are pumped by a 775nm CW laser. The down converted photons have a center wavelength of 1550 nm and are further filtered using Fiber Bragg Gratings with 45pm bandwidth at the wavelengths of 1530 nm (signal) and 1570 nm (idler) for each pair. The signal photons interfere in a beam splitter and the four-fold coincidence rate is measured using a time-tagging device, yielding over 150 counts per hour.

The present work is the first step towards high-efficient time-energy entanglement swapping between asynchronous sources.

Q 31.4 Wed 11:45 HS 3219

Experimental boosted linear-optical Bell-state measurement — •Nico Hauser, Matthias Bayerbach, Simone D'Aurelio, and Stefanie Barz — Universität Stuttgart, Institut für funktionelle Materie und Quantentechnologien

Bell-state measurements are integral to many quantum communication and computation protocols. The conventional scheme for a linear-optical Bell-state measurement provides only a definite identification for two out of the four Bell states, resulting in an overall efficiency of 50%. Here we implement a scheme that significantly increases this efficiency by using an entangled ancillary photon pair and a fibre-based balanced 4x4 splitter. Using this scheme, we achieve a significant increase of the Bell-state measurement efficiency compared to the standard scheme.

Q 31.5 Wed 12:00 HS 3219

Quantum communication protocols over the 14-km Saarbrücken fiber link — •Christian Haen, Stephan Kucera, Elena Arenskötter, Jonas Meiers, Tobias Bauer, and Jürgen Eschner — Universität des Saarlandes, Saarbrücken, Deutschland

Existing telecom-fiber infrastructure provides the basis for creating large scale quantum networks, potentially leading to the implementation of a quantum internet. The deployment of glassfibers for this purpose poses certain challenges, especially in urban areas, such as large disturbances in polarization.

We report on a 14-km long dark fiber link running across the Saarbrücken urban area, which we characterize for quantum networking by transmission of polarization- or time-bin-encoded photonic quantum bits. We stabilize the polarization of the fiber link and demonstrate quantum networking operations using a 40Ca+ single-ion quantum memory, an ion-resonant entangled photon-pair source, and quantum frequency conversion from the atomic wavelength to the telecom C-band. We realize dual-wavelength photon-photon entanglement, entanglement between an ion and a telecom photon, and teleportation of a qubit state from the ion onto a telecom photon transmitted over the link.

Q 31.6 Wed 12:15 HS 3219

Towards polarization entanglement distribution in a metropolitan dark-fibre network in Berlin — •William Staunton[1], Sebastian Brauner[2], Kai-Hong Luo[2], Harald Herrmann[2], and Oliver Benson[1] — [1]Humboldt University, Berlin, Germany — [2]Paderborn University, Paderborn, Germany

Efficient distribution of entanglement is essential in the potential realization of a quantum internet[1]. Thanks to the maturity of the classical telecommunications industry, a worldwide network of single-mode optical optical fibres is already in existence. With such an infrastructure and quantum repeater functionalities we could move towards distributed quantum computation and quantum communication on a global scale. We present the work towards polarization entanglement distribution in a metropolitan, field-installed dark-fibre network in Berlin. With focus on results of the active polarization stabilization employed. We also introduce the novel, degenerate, resonant, type-II periodically poled Lithium Niobate (PPLN) spontaneous parametric down-conversion (SPDC) waveguide source[2] producing entangled photon pairs with high brightness and narrow linewidth. Crucially, such sources emit photons with pure spectral states. With an emission bandwidth optimized for interacting with quantum memories, we show how the source is optimized for quantum repeater demonstrations. [1] Kimble, H. J. (2008). The quantum internet. Nature, 453(7198), 1023*1030. [2] K.-H. Luo et al., Phys. Rev. Lett. 115, 200401 (2015).

Q 31.7 Wed 12:30 HS 3219

Deployment and optimization of high-dimensional QKD on a 1.7 km free-space link — •Karolina Paciorek[1], Christopher Spiess[1,2], Sarika Mishra[1], and Fabian Steinlechner[1,2] — [1]Fraunhofer Institute for Applied Optics and Precision Engineering, Albert-Einstein-Strasse 7, Jena 07745, Germany — [2]Friedrich Schiller

University, Institute of Applied Physics, Abbe Center of Photonics, Albert-Einstein-Strasse 15, Jena 07745, Germany

Quantum Key Distribution (QKD) is a method for establishing a secure encryption key using a quantum optical sender, a transmission link, and an optical receiver. When QKD is implemented over short distances with low losses, such as in data centers or intercity links, then the maximum secure key rate is typically limited by saturation of the single-photon detectors at the receiver. To overcome this limitation, high-dimensional QKD protocols can be implemented.

High-dimensional QKD protocols enable encoding more information into one photon, which enables operation at photon rates that no longer saturate the detectors. We show this at the example of a weak coherent source in a time-phase encoding scheme. Furthermore, we demonstrate the transfer of key material over a 1.7 km intercity free-space link. Our demonstration is accompanied by finite-key analysis together with an extensive parameter optimization in experiment and simulations to maximize the key rate. Our results show that high-dimensional QKD with weak coherent sources is a promising avenue towards versatile communication scenarios, including areas with difficult access such as rapidly changing metropolitan spaces or in satellite communication.

Q 31.8 Wed 12:45 HS 3219

A quantum frequency converter for entanglement distribution across a metropolitan network — •Maya Büki, Gianvito Chiarella, Tobias Frank, Pau Farrerra, Emanuele Distante, and Gerhard Rempe — Max-Planck-Institute for Quantum Optics, Garching, Germany

Single atoms in a cavity serve as a suitable building block for quantum networks as cavities offer an ideal interface between light and matter qubits in terms of both efficiency and fidelity. Within this scope, we can efficiently entangle the spin states of Rubidium (Rb) atoms with optical polarization qubits. Despite offering numerous capabilities for quantum networks, such as being a source of (complex) atom-photon entanglement, enabling heralding quantum memories, and facilitating quantum repeaters, there is a drawback when aiming for long-distance quantum networks, and that is the wavelength of the optical qubit at $\lambda_{\mathrm{Rb}} = 780$ nm, causing intrinsic fiber losses to be quite high.

To circumvent these losses, a quantum frequency conversion to the telecom regime becomes necessary. Here, we demonstrate a quantum frequency converter (QFC) that exhibits a good efficiency and high signal-to-noise ratio. Alongside a narrow filtering system this QFC will be employed to connect two quantum nodes through 23km of optical fiber across the metropolitan area of Munich. We will present preliminary results about this fiber channel outside the lab, with the prospect of distributing entanglement across a real world quantum network link.