Q 60: Quantum Communication, Networks, Repeaters, & QKD II

Time: Thursday 14:30–16:30 Location: P 10

Invited Talk Q 60.1 Thu 14:30 P 10

Towards entangling distributed registers of atoms — •Ben Lanyon — Institut für Experimentalphysik, Universität Innsbruck, Technikerstasse 25, 6020 Innsbruck, Austria

We are developing methods to entangle remote registers of atoms over distances ranging from a few meters to hundreds of kilometers or more. Such distributed atomic quantum networks could enable new applications in sensing, timekeeping, computing, and communication, and are being pursued worldwide using a variety of approaches. Our approach employs network nodes that each consist of a register of electrically trapped atomic ions (calcium), integrated with an optical cavity for efficient atom-photon interaction, and a separate nonlinear optical process to convert ion emitted photons to telecom wavelengths. Full deterministic quantum logic is available on qubits encoded within the atomic register, allowing each node to function as a small-scale, photon interfaced quantum processor. In this talk, I will summarise one or two of our recently published results — including a photon interfaced ten qubit register of trapped ions [1] — or alternatively present some unpublished work, depending on progress in the months before the conference.

[1] M. Canteri et al., Photon interfaced ten qubit register of trapped ions, Phys. Rev. Lett. 135, 080801 (2025).

Q 60.2 Thu 15:00 P 10

Highly Indistinguishable Single Telecom Photons from a Tin-Vacancy-Center in Diamond — •David Lindler, Tobias Bauer, Dennis Herrmann, Robert Morsch, Marlon Schäfer, and Christoph Becher — Universität des Saarlandes, FR Physik, Campus E2.6, 66123 Saarbrücken

Tin-vacancy centers (SnV) in diamond are a promising platform for quantum nodes in quantum communication networks, exhibiting excellent optical and spin coherence [1,2]. To connect these nodes over long distances via optical fiber links, such as in a quantum repeater, it is necessary to first generate entanglement between each quantum node and a photon. The photons are then converted into the low-loss telecom C-band using quantum frequency down-conversion to mitigate the high losses associated with the visible wavelength of the SnV center photons. Performing a Bell-state measurement on the photons enables entanglement swapping, resulting in a pair of entangled remote quantum nodes. Achieving a quantum-repeater advantage over direct transmission requires the photons to be highly indistinguishable to ensure successful Bell-state measurements with high fidelity.

We present the generation of highly indistinguishable photons in the telecom band that are emitted sequentially by a single SnV center. The indistinguishability of the photons, measured via Hong-Ou-Mandel interference, reaches a visibility of over 95% before, and over 90% after frequency conversion to the telecom C-band, respectively.

[1] J. Görlitz et al., npj Quant. Inf. 8, 45 (2022).
[2] I. Karapatzakis et al., Phys. Rev. X 14, 031036 (2024).

Q 60.3 Thu 15:15 P 10

Quantum repeater segment based on trapped ions with telecom interface — •Max Bergerhoff, Pascal Baumgart, Jonas Meiers, Christian Haen, Tobias Bauer, Christoph Becher, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany

The quantum repeater (QR) segment enables the connection between distant quantum computers and is, as part of a QR link [1], a fundamental building block for the realization of large-distance quantum networks. By dividing a transmission link in segments and cells [2], it is possible to overcome the exponential attenuation of direct transmission. To reduce losses, the photonic channel must operate at telecom wavelength.

We report on the implementation of a QR segment with free-space coupled photons from two $^{40}Ca^{+}$ ions in the same Paul trap as quantum memories. Atom-photon entanglement is generated [3] by controlled emission of single 854-nm photons from the ions after excitation with nanosecond laser pulses and separate single-mode fiber coupling. Atom-atom entanglement is then generated by a photonic Bell-state measurement after conversion of the 854 nm photons to 1550 nm. In this context, the perspective of a heterogeneous QR segment using a trapped $^{40}Ca^{+}$ ion and a SnV color center in diamond is discussed.

[1] P. van Loock et al., Adv. Quantum Technol., 3: 1900141 (2020).
[2] M. Bergerhoff et al., Phys. Rev. A 110, 032603 (2024).
[3] M. Bock et al., Nat. Commun. 9, 1998 (2018).

Q 60.4 Thu 15:30 P 10

The influence of back-decays on the indistinguishability of single Raman photons — •Pascal Baumgart, Max Bergerhoff, Jonas Meiers, Stephan Kucera, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany

The ability to generate indistinguishable single photons capable of high-contrast Hong-Ou-Mandel (HOM) interference is the keystone for implementing entanglement swapping protocols based on photonic Bell state measurements, which may be used to realise quantum repeater schemes [1] or connect quantum processing units in distributed quantum computing [2]. One method to generate single photons is laser excitation of a Raman transition with a stable ground state and a short-lived excited state that decays to a third meta-stable state under the emission of a Raman photon. However, the indistinguishability of these photons is influenced by the possibility of back-decay to the ground state and subsequent re-excitation on the driven transition, which broadens the photonic temporal wave packet beyond the Fourier limit [3]. We investigate this behavior for trapped $^{40}Ca^{+}$ ions using few-nanosecond excitation pulses. Numerical simulations identify the mean number of back-decays as a measurable quantity that correlates with achievable HOM visibility. This is supported by experimental data.

[1] P. van Loock et al., Adv. Quantum Technol. 3, 1900141 (2020)
[2] J. O'Reilly et al., Phys. Rev. Lett. 133, 090802 (2024)
[3] P. Müller et al., Phys. Rev. A 96, 023861 (2017)

Q 60.5 Thu 15:45 P 10

Long-distance quantum communication sending single photons and keeping many — •Stefan Häussler and Peter van Loock — Institute of Physics, Johannes Gutenberg-Universität Mainz, Staudingerweg 7, 55128 Mainz, Germany

We describe all-optical memory-based quantum repeaters for long-distance quantum communication, with memories realized in the form of fiber loops located in the repeater stations. The memories can be used to store components of logical Bell states encoded in quantum error correction codes and offer the possibility of performing teleportation-based error correction. By sending only single-photon states through the fibers connecting the stations, such repeaters can operate in the long-segment regime compatible with existing fiber-based communication infrastructure. We analyze the performance of our scheme for the Gottesman-Kitaev-Preskill code, including a concatenation with the Steane code, as well as the Quantum Parity Code, identifying operational regimes for total distances up to 10000km.

Q 60.6 Thu 16:00 P 10

Advanced Quantum Communication and Quantum Networks - From basic research to future applications — Björn Kubala, Alexander Sauer, •Alessandro Tarantola, and Matthias Zimmermann — German Aerospace Center (DLR), Institute of Quantum Techologies, Wilhelm-Runge-Straße 10, Ulm, 89081, Germany

The fast and reliable global classical communication enabled by the birth of the Internet brought about a cultural, economic and social revolution, and opened the door to previously unthinkable applications. Many observers believe a similar revolution is bound to take place, once the Quantum Internet, coherently connecting quantum devices (sensors, computers, memories,...), is established. In this talk, we provide an overview of concrete distributed quantum applications, mainly in the field of quantum security, that will be made feasible by the rise of the Quantum Internet. Moreover, we argue that the theoretical investigation of distributed quantum protocols is crucial in steering the next hardware- and infrastructure-development steps.

This talk is based on joint work within the "Physikalische Grundlagen der Quanteninformation, -kommunikation und -verarbeitung" project.

Q 60.7 Thu 16:15 P 10

Connecting Neutral-Atom Quantum Nodes across a metropolitan fiber link — •Tobias Frank[1], Pooja Malik[2], Maya Büki[1], Gianvito Chiarella[1], Florian Fertig[2], Yiru Zhou[2], Pau Farrera[1,3], Harald Weinfurter[1,2], and Gerhard Rempe[1] — [1]Max Planck Institute of Quantum Optics, Garching, Germany — [2]Ludwig-Maximilians-University, Munich, Germany — [3]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany

Neutral atoms are promising candidates for quantum networking due to their long coherence times, uniform optical transitions, and efficient light-matter interfaces. A central challenge is distributing high-fidelity entanglement between remote network nodes over metropolitan fiber links, where loss and environmental noise are significant.

We address this by interconnecting two neutral-atom quantum nodes via a 23.7 km deployed telecom fiber link in the Munich metropolitan area. Using active polarization stabilization and quantum frequency conversion to the telecom S-band at the sender, we distribute atom-photon entanglement with minimal transmission loss. At the receiver, telecom photons are back-converted to 780 nm and stored in a passively heralded memory, providing a low-noise indication of successful storage. With Spin-echo techniques we extend the memory coherence time, while using microwave qubit rotations combined with fluorescence-based detection we can enhance the readout efficiency, both essential requirements for high-fidelity entanglement distribution between the two distant nodes.