Q 81: Quantum Communication, Networks, Repeaters, & QKD III

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

Q 81.1 Fri 14:30 P 10

Device-independent quantum key distribution in an event-ready atom-photon architecture over 25 km fiber using double frequency conversion — •Jonas Meiers, Christian Haen, Max Bergerhoff, Tobias Bauer, Christoph Becher, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany

Quantum cryptographic protocols offer physical security through no-cloning or entanglement. Following the device-independent quantum key distribution protocol of [1], we present our event-ready implementation based on entanglement between a single atom and its emitted photons. The protocol requires four atomic bases and two photonic bases and allows us to create a quantum key with security verification via the Bell parameter. We employ polarization entanglement between a single trapped $^{40}Ca^+$ ion and an emitted photon at 854 nm, generated on the $P_{3/2} \rightarrow D_{5/2}$ transition via Raman scattering [2]. The photon is frequency-converted to the telecom band, enabling its transmission over a 25-km-long, polarization-stabilized fiber spool, and afterwards reconverted to 854 nm before state projection. The projected qubits enable key generation after classical post-processing, including error correction and privacy amplification. Future applications include our 15-km-long urban fiber as quantum link, that has already been characterized and demonstrated [3].

[1] R. Schwonnek et al., Nat. Commun. 12, 2880 (2021)
[2] M. Bock et al., Nat. Commun. 9, 1998 (2018)
[3] S. Kucera et al., npj Quantum Inf. 10, 88 (2024)

Q 81.2 Fri 14:45 P 10

Polarization to time-bin conversion for ion-photon entanglement — •Christian Haen[1], Julian Gross-Funk[1,2], Max Bergerhoff[1], Pascal Baumgart[1], Tobias Bauer[1], Christoph Becher[1], and Jürgen Eschner[1] — [1]Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany — [2]see below

Conversion between photonic polarization qubits and time-bin qubits enables the creation of hybrid quantum networks using different quantum memory platforms such as ions and color centers, that provide different inherent types of memory-photon entanglement. For large-scale networks, time-bin encoded quantum information is also less susceptible to polarization changes.

Here, we demonstrate the preservation of ion-photon entanglement after conversion from polarization to time-bin qubits using a telecom fiber-based encoding interferometer. We utilize a single $^{40}Ca^+$ ion in a Paul trap as quantum memory to generate photons that are polarization-entangled with the ion. Additionally, we use quantum frequency conversion to 1550 nm, which is the operating wavelength of the qubit converter, enabling low loss transmission over large distance telecom fiber links [1]. A second quantum frequency converter is used to finally return to the ion transition wavelength.

[1] S. Kucera et al., npj Quantum Inf. 10, 88 (2024).

[2] presently at German Aerospace Center (DLR), Institute of Quantum Technologies, 89081 Ulm, Germany

Q 81.3 Fri 15:00 P 10

Progress towards Intercity Quantum Key Distribution with Deterministic Sources — •Joscha Hanel[1], Fabian Klingmann[2], Jingzhong Yang[1], Jipeng Wang[1], Vincent Rehlinger[1], Zenghui Jiang[1], Jialiang Wang[1], Eddy Patrick Rugeramigabo[1], Raphael Joos[3], Michael Jetter[3], Ali Hreibi[4], Ann-Katrin Kniggendorf[4], Simone Luca Portalupi[3], Peter Michler[3], Stefan Kück[4], Tara Liebisch[1], Michael Zopf[1], and Fei Ding[1,5] — [1]Institut für Festkörperphysik, Leibniz Universität Hannover — [2]Fraunhofer-Institut für Photonische Mikrosysteme, Dresden — [3]Institut für Halbleiteroptik und Funktionelle Grenzflächen, IQST and SCoPE, University of Stuttgart — [4]Physikalisch-Technische Bundesanstalt, Braunschweig — [5]Laboratorium für Nano-und Quantenengineering, Leibniz Universität Hannover

We report on the progress toward a deployed QKD system based on a deterministic quantum dot single photon source, and toward its practical operation on the 78 km Niedersachsen Quantum Link connecting Hannover and Braunschweig.

The system employs high-fidelity polarization encoding at a 152 MHz excitation rate and advanced polarization stabilization to maintain low-error performance and generate keys at practical rates. We further develop and implement a remote clock synchronization scheme that leverages the timing information present within the quantum signal. Our findings underline the viability of deterministic quantum emitters for scalable, real world quantum communication applications.

Q 81.4 Fri 15:15 P 10

Stand-alone mobile quantum memory system — •Martin Jutisz[1], Alexander Erl[2,3], Janik Wolters[2,3], Mustafa Gündoğan[1], and Markus Krutzik[1,4] — [1]Humboldt-Universität zu Berlin and CSMB Adlershof, Berlin, Germany — [2]Technische Universität Berlin, Berlin, Germany — [3]Deutsches Zentrum für Luft- und Raumfahrt, Berlin, Germany — [4]Ferdinand-Braun-Institut (FBH), Berlin, Germany

Quantum memories (QMs) are pivotal to many areas of quantum information science, most notably quantum repeaters. Therefore, these devices must be capable of operating in non-laboratory environments, even in space. Warm-vapour QMs are especially appealing for this purpose because of their simplicity and ease of operation.

We will present the implementation and performance analysis of a portable, standalone warm vapour quantum memory system [1]. The memory operates with weak coherent pulses of less than one photon per pulse. We demonstrate the memory's long-term stability over a 28-hour period, including operation in a non-laboratory environment. We also report ongoing progress in miniaturising the memory platform and demonstrating storage of heralded single photons generated via spontaneous parametric down-conversion.

[1] M. Jutisz et al., Phys. Rev. Applied 23, 024045 (2025).

Q 81.5 Fri 15:30 P 10

A Compact Receiver for Polarisation Encoded BB84 Quantum Key Distribution — •Michael Steinberger[1,2], Moritz Birkhold[1,2], Michael Auer[1,2,3], Adomas Baliuka[1,2], Harald Weinfurter[1,2,4], and Lukas Knips[1,2,4] — [1]Ludwig Maximilian University (LMU), Munich, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany — [3]Universität der Bundeswehr, Neubiberg, Germany — [4]Max Planck Institute of Quantum Optics (MPQ), Garching, Germany

Quantum Key Distribution (QKD) enables the secure exchange of secret keys, by exploiting the laws of quantum mechanics. Free-space optical communication allows for a range of different QKD use-cases, including short ground-to-ground links for urban environments up to key exchange with satellites. Current hardware uses telescopes with complex optics and highly efficient single-photon detection devices. To make QKD suitable for scenarios offering less space and profiting from a higher degree in mobility, our goal is to develop very compact and integrated detection systems for polarization-encoded BB84 QKD. We demonstrate a miniaturized polarisation analysis unit (PAU) on the millimeter scale. To be used with CMOS single photon avalanche detector arrays these concepts - trading in performance - achieve a new level of of scalability and integrability.

Q 81.6 Fri 15:45 P 10

QKD via Nanosatellites - Qube 2 Mission Hardware and Update — •Moritz Birkhold for the QUBE 2 Konsortium-Collaboration — Ludwig Maximilian University (LMU) — Munich Center for Quantum Science and Technology (MCQST)

Since the first proposal of the BB84 protocol in 1984, Quantum Key Distribution (QKD) has progressed from laboratory demonstrations to large-scale deployed fiber-based networks of 2000+ km in China. However, the limited reach of terrestrial links continues to motivate the development of space-based QKD to achieve global coverage. As a first step towards this goal, the QUBE-1 pathfinder mission, launched in 2024 with compact optical payloads but without full QKD capability, has enabled initial quantum experiments in orbit.

Building on the technologies and experience gained from these, the successor mission QUBE-2 now will introduce several major upgrades to enable full QKD operation from a nanosatellite platform. The optical terminal now includes an enlarged 8 cm aperture, improving link performance, while the fully re-engineered optical assembly is hermetically sealable and more reproducible. The QKD electronics supports repetition rates up to 200 MHz, incorporates decoy-state capability, and can perform all required post-processing tasks. Ground validation demonstrated key exchange with QBER $< 0.5\%$. The payloads have successfully passed testing, are already integrated with the satellite bus and prepared for launch in 2026.

Q 81.7 Fri 16:00 P 10

Narrow-band resonator-enhanced SPDC source for airborne quantum communication — Sheng-Hsuan Huang[1,2], •Thomas Dirmeier[1,2], Hans Dang[1,2], Sebastian Luff[1,2], Martin Fischer[1], Markus Sondermann[1,2], Gerd Leuchs[1,2], and Christoph Marquardt[2,1] — [1]Max Planck Institute for the Science of Light, Staudtstr 2, 91058 Erlangen — [2]Department of Physics, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr 7/A3, 91058 Erlangen

Long-distance quantum communication networks rely on the ability to faithfully distribute quantum information between different network nodes, which are often considered based on from atomic or ionic systems. Efficient information transfer not only relies on a low-loss quantum channel but also requires sources that generate quantum states which can interact with the atom or ion in question. Whispering gallery mode resonator (WGMR) based SPDC sources have been shown to be highly tunable sources for a variety of quantum states. Their inherent optical bandwidth in the MHz-range making them compatible to atomic and ionic transitions.

As part of the German QuNET initiative, we are employing our WGMR-based source aboard a research aircraft of the German DLR. Together with a ground station by Fraunhofer IOF. We are investigating the coupling of photonic quantum states to a single trapped ion under adverse conditions from an airborne free-space link.

In our presentation, we highlight the challenges of realizing photon-atom-interaction experiments in such a demanding environment.

Q 81.8 Fri 16:15 P 10

Fully Integrated Multifunctional Platform for Secure QKD Using Waveguide-Integrated SNSPDs — •Connor A. Graham-Scott[1,2,3], César Bertoni Ocampo[1,2,3], Janis Averbeck[1,2,3], and Carsten Schuck[1,2,3] — [1]Department for Quantum Technology, University of Münster, Germany — [2]Center for NanoTechnology - CeNTech, Münster, Germany — [3]Center for Soft Nanoscience - SoN, Münster, Germany

Quantum key distribution (QKD) is a central technology for secure quantum communications, yet current implementations are typically limited in scalability and functionality, e.g. lacking capabilities for guaranteeing signal integrity. The challenge is to achieve a compact, fully integrated platform that not only performs QKD but also detects sophisticated eavesdropping attempts and provides redundancy through alternative encryption pathways.

Here, we present a multifunctional, fully integrated system on a single chip combining several functional blocks based on waveguide-integrated superconducting nanowire single-photon detectors (WI-SNSPDs). Our system combines time-bin COW QKD with a 200-ps delay line, intrinsic and statistical photon-number-resolution methods, polarization-independent operation, and the detection of intercept-resend blinding attacks. By leveraging high-efficiency and low-jitter performance of correspondingly configured WI-SNSPDs, the system allows for both high key generation rates and enhanced security, while remaining scalable and suitable for full integration in future quantum communication systems.