Q 58: Quantum Communication II: Implementations (joint session QI/Q)

Time: Thursday 14:30–16:30 Location: HS IX

Q 58.1 Thu 14:30 HS IX

Darmstadt quantum local area network (DaQLAN) — •Maximilian Tippmann[1], Florian Niederschuh[1], Maximilian Mengler[1], Erik Fitzke[2], Oleg Nikiforov[2], and Thomas Walther[1] — [1]TU Darmstadt, Institute of Applied Physics, 64289 Darmstadt — [2]Deutsche Telekom Technik GmbH, Darmstadt, Deutschland

Quantum computers can threaten today's IT infrastructure e.g. by implementing Shor's algorithm. Quantum key distribution (QKD) enables users to share a random secret, thus offering resilience against such attacks by choosing other cryptographic primitives. Many QKD systems based on various protocols have been tested. Often, these protocols are susceptible to drifts in the properties of the transmission link (e.g. changing polarization) and do not offer scalability to more than two users, hence, they are not ideal for real-world applications. We present a city-wide field test of our star-shaped QKD network enabling scalability to more than 100 users. A central untrusted node acts as a photon pair source. The phase-time coding protocol makes our setup independent of polarization drifts in the transmission links. We show results with four parties all being placed at different locations within the city and connected via field-deployed fibers exchanging pairwise keys. Our system features a complete post-processing allowing to generate real-time secure keys. Additionally, we demonstrate the plug-and-play flexibility of our network by showcasing various operation modes and combinations of receiver pairs.

Q 58.2 Thu 14:45 HS IX

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) provides secure exchange of shared secret keys, solely 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 stallites. 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 a very compact and integrated detection system for polarization-encoded BB84 QKD. We show how using a CMOS single photon avalanche detector array (provided by the Technical University of Vienna) with new compact electronics - trading in performance - the scalability and integrability can be clearly increased. Together with a microoptics based concept this enables a miniaturized polarisation analysis unit (PAU) on the millimeter scale.

Q 58.3 Thu 15:00 HS IX

Optical system for bi-directional tracking in free-space quantum key distribution link — •Akhil Gupta[1,4], Michael Auer[1,3,4], Michael Steinberger[1,4], Adomas Baliuka[1,4], Moritz Birkhold[1,4], Manpreet Kaur[1,2,4], Harald Weinfurter[1,2,4], and Lukas Knips[1,2,4] — [1]Ludwig Maximilian University of Munich, Munich, Germany — [2]Max Planck Institute of Quantum Optics, Garcing, Germany — [3]Universität der Bundeswehr München , Munich, Germany — [4]Munich Center for Quantum Science and Technology, Munich, Germany

Quantum Key Distribution (QKD) offers a secure alternative to traditional cryptographic algorithms to generate shared secret keys. We aim to establish a secure ground-to-ground communication on the few kilometers scale using simple and sturdy systems. This talk highlights the critical role of telescopes in free-space communication, enabling efficient signal transmission and reception. Our symmetrical telescope design functions as both transmitter and receiver, optimized for 850 nm (QKD signal) and 1550 nm (tracking, synchronization, and classical communication). The system addresses atmospheric challenges to ensure bidirectional stability, enabling low-loss transmission for reliable and secure quantum communication.

Q 58.4 Thu 15:15 HS IX

Frequency conversion in a hydrogen-filled hollow core fiber — •Anica Hamer[1], Frank Vewinger[2], Thorsten Peters[3], and Simon Stellmer[1] — [1]Physikalisches Institut, Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, Germany — [2]Institut für Angewandte Physik, Rheinische Friedrich-Wilhelms-Universität Bonn, Bonn, Germany — [3]Institut für Angewandte Physik, Technische Universität Darmstadt, Darmstadt, Germany

Quantum networks, as envisioned for quantum computation and quantum communication applications, are based on a hybrid architecture. Such a layout may include solid-state emitters and network nodes based on photons as so-called flying qubits. This concept requires an efficient and entanglement-preserving exchange of photons between the individual components, which often entails frequency conversion of the photon.

Our approach is based on coherent Stokes Raman scattering (CSRS) in a dense molecular hydrogen gas. This four-wave mixing process sidesteps the limitations of nonlinear crystals, it is intrinsically broadband and does not generate an undesired background. We present broadband and polarization-preserving frequency conversion in a hydrogen-filled anti-resonant hollow-core fiber between 863 nm (InAs/GaAs quantum dots) and the telecom O-band. Disparate from related experiments that employ a pulsed pump field, we here take advantage of two coherent continuous-wave pump fields.

Q 58.5 Thu 15:30 HS IX

QUBE-II: Compact and economical satellite-based quantum key distribution — •Joost Vermeer for the QUBE-II-Collaboration — Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen, Germany — Max Planck Institute for the Science of Light (MPL), Staudtstr. 2, 91058 Erlangen, Germany

The range of fiber-based quantum key distribution (QKD) systems is limited by the fiber's attenuation. To overcome this limit, several projects have been started in the past decade to develop satellite-based QKD systems. The cost of these systems is for a large part determined by the size, weight and power of the satellite.

Built upon predecessor mission QUBE, the goal of the QUBE-II mission is to use a small 8U CubeSat ($10 \times 20 \times 40$ cm^3) to perform QKD between the CubeSat and a ground station. Two integrated QKD transmitters implement polarization- and phase-encoded versions of the BB84 decoy protocol. Random optical quantum states are generated using a photonic integrated onboard quantum random number generator and transmitted to the ground station using an 80 mm optical telescope. For post-processing the same optical path is used to establish a bidirectional classical data link.

In this work, we will present the nominal operations of the QUBE-II mission. We will discuss the requirements needed for a successful QKD link and a secure quantum key, the effect hardware limitations have on the requirements and the effect these requirements have on the hardware design.

Q 58.6 Thu 15:45 HS IX

QKD satellite QUBE - Launched and commissioned — •Moritz Birkhold für die QUBE Konsortium-Kollaboration — Ludwig Maximilian University, Munich, Germany — Munich Center for Quantum Science and Technology (MCQST), Schellingstr. 4, D-80799 Munich, Germany

Since its inception in 1984, ongoing efforts have been made to bring the distinct advantages of Quantum Key Distribution (QKD)- secure generation of a cryptographic key-into practical use outside of laboratory environments. With the emergence of larger and longer fiber-based QKD networks used in urban environments, solutions for a truly global QKD backbone are being sought. Using satellites as trusted nodes can offer this solution.

The QUBE missions attempt to achieve downlink QKD with small nanosatellites using the CubeSat platform. Extensive development produced energy-efficient electronics and highly compact, robust optics based on vertical-cavity surface-emitting lasers and integrated photonics, to make this scalable form factor usable. The first of these satellites QUBE, a pathfinder mission towards QKD with nanosatellites, was launched in August 2024 and is currently in the comissioning phase, allowing for the first QKD experiments in Q1 of 2025. We will show the most recent progress of the project, most recent ground measurements as well as updates on the measurement campaign, that will lead towards the sucessor mission QUBE 2, a nanosatellite with full QKD capabilities.

Q 58.7 Thu 16:00 HS IX

Pulse shape optimization against Doppler shifts and delays in optical quantum communication — •Emanuel Schlake[1,2,3], Roy Barzel[1,2], Dennis Rätzel[1,2], and Claus Lämmerzahl[1,2] — [1]ZARM, University of Bremen, 28359 Bremen, Germany — [2]Gauss-Olbers Space Technology Transfer Center, University of Bremen, 28359 Bremen, Germany — [3]Department of Communications Engineering, University of Bremen, 28359 Bremen, Germany

High relative velocities and large distances in space-based quantum communication with satellites in lower earth orbits can lead to significant Doppler shifts and delays of the signal impairing the achievable performance if uncorrected. We analyze the influence of systematic and stochastic Doppler shift and delay in the specific case of a continuous variable quantum key distribution (CV-QKD) protocol and identify the generalized correlation function, the ambiguity function, as a decisive measure of performance loss. Investigating the generalized correlations as well as private capacity bounds for specific choices of spectral amplitude shape (Gaussian, single- and double-sided Lorentzian), we find that this choice has a significant impact on the robustness of the quantum communication protocol to spectral and temporal synchronization errors. We conclude that optimizing the pulse shape can be a building block in the resilient design of quantum network infrastructure.

Q 58.8 Thu 16:15 HS IX

Dynamic Polarization State Preparation for Single-Photon Quantum Cryptography — •Anastasios Fasoulakis, Koray Kaymazlar, Martin von Helversen, and Tobias Heindel — Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany

Quantum Key Distribution (QKD) is the most developed application in the field of quantum information science. Prepare-and-measure type protocols thereby rely on a fast, random qubit-state preparation. In this contribution we discuss our progress in the development of fast polarization-state encoders for single-photon implementations of BB84-QKD as well as cryptographic primitives beyond QKD. Using high-bandwidth free-space optical as well as fiber-based electro-optical modulators in combination with commercial and self-built control-electronics, solid-state quantum light sources emitting at different wavelengths can be modulated. We characterise and optimise the system's performance in terms of its extinction ratio and repetition rate and gauge its potential applications in future QKD systems.