QI 8: Quantum Communication I (joint session Q/QI)

Time: Monday 17:00–19:00 Location: F442

QI 8.1 Mon 17:00 F442

Eavesdropper location inside quantum channel using nonlinear optics — •Alexandra Popp[1,2], Birgit Stiller[1,2], and Christoph Marquardt[1,2] — [1]Max Planck Institute for the Science of Light (MPL), Erlangen, Germany. — [2]Department of Physics, University of Erlangen-Nürnberg (FAU), Erlangen, Germany.

Secure communictation is highly important in today's information age. Quantum key distribution uses the laws of quantum mechanics to offer secure key exchange between two parties. A key feature of this is the notice of eavesdropping through changes to the quantum bit error rate or excess noise of the quantum channel. Once the eavesdropper is detected, it however needs to be localized and removed from the communication channel. In a quantum channel, this can be especially challenging. We present a novel idea for localizing eavesdroppers on the cm level within quantum as well as classical communication channels using localized acoustic waves created by a correlation-based technique. Amongst other interception techniques, we show that our setup is capable of detecting interception by evanescent outcoupling with as low as 1% outcoupling.

QI 8.2 Mon 17:15 F442

Hacking QKD Sender Electronics Using Deep Learning — •Adomas Baliuka[1,2], Markus Stöcker[1,2], Michael Auer[1,2,3], Peter Freiwang[1,2], Harald Weinfurter[1,2,4], and Lukas Knips[1,2,4] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, 80799 München — [2]Munich Center for Quantum Science and Technology, 80799 München — [3]Universität der Bundeswehr, 85577 Neubiberg — [4]Max-Planck-Institut für Quantenoptik, 85748 Garching

Quantum key distribution (QKD) promises provably secure communication. However, the proofs make assumptions which have to be met carefully in practical implementations. Violations of the assumptions open up *side channels*, which enable an eavesdropper to obtain secret information. For a QKD sender, imperfections in quantum state preparation can lead to *quantum side channels* by encoding secret information in degrees of freedom (e.g., frequency, spatial mode) not protected by the QKD protocol. On the other hand, information can also leak via *classical side channels*, such as acoustic vibrations or classical electromagnetic emissions.

We analyze electromagnetic emissions from the electronics of our home-built BB84 QKD sender at a distance of a few centimeters. We are able to extract virtually all information about the secret key using a neural network and even observe traces of electromagnetic radiation at distances of up to a few meters. We discuss countermeasures and evaluate a revised electronics design, showing a significant reduction of emissions and attack performance.

QI 8.3 Mon 17:30 F442

Atomic arrays based on optical tweezers at the center of an optical cavity — •Lukas Hartung, Matthias Seubert, Stephan Welte, Emanuele Distante, and Gerhard Rempe — Max-Planck Institut für Quantenoptik, Hans-Kopfermann-Str.1, 85748 Garching

Future quantum networks require multi-qubit network nodes that are capable to manipulate and process quantum information locally and distribute entanglement over the entire network. Therefore, a variety of fundamental qubit-operations and quantum gates are necessary and were already demonstrated, e.g. single qubit-rotations, local [1] and remote qubit-gates [2] and efficient atom-photon entanglement [3]. However, scaling up to many qubits at one node remains an outstanding challenge.

In this talk, we present the generation of arrays of rubidium 87 atoms in an optical cavity. The atoms are loaded and trapped in an optical lattice probabilistically and are then rearranged within the lattice with the help of optical tweezers. In this way, we increase the rate of generation of atomic arrays by orders of magnitudes and, in principle, preserve the capabilities already demonstrated in the past.

[1] Welte, Stephan, et al., Photon-Mediated Quantum Gate between Two Neutral Atoms in an Optical Cavity, Phys. Rev. X 8, 011018 (2018)

[2] Daiss, Severin, et al., A quantum-logic gate between distant quantum-network modules, Science 371, 614 (2021)

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

QI 8.4 Mon 17:45 F442

Quantum communication protocols over a 14 km urban fiber link — •Stephan Kucera, Elena Arenskötter, Christian Haen, Jonas Meiers, Tobias Bauer, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken

The application of existing telecom-fiber infrastructure for quantum communication protocols enables efficient development of quantum networks [1]. It also entails multiple challenges, since existing infrastructure in an urban region is often underground, or paired with the electrical overhead power line.

We report on the implementation of entanglement distribution and quantum-state teleportation over a 14 km polarization-stabilized urban dark-fiber link, which is partially underground, partially overhead, and patched in several stations. Using a type-II cavity-enhanced SPDC photon-pair source, a ^{40}Ca^{+} single-ion quantum memory whose transition matches the source, and quantum frequency conversion to the telecom C-band of one photon of a pair [2], we demonstrate photon-photon entanglement, ion-photon entanglement, and teleportation of a qubit state from the ion onto the remote telecom photon, all realized over the urban fiber link.

[1] H. Kimble, Nature 453, 1023*1030 (2008)
[2] E. Arenskötter et al., arXiv:2211.08841 (2022)

QI 8.5 Mon 18:00 F442

Free-space continuous-variable quantum key distribution using discrete modulation — •Kevin Jaksch[1,2], Thomas Dirmeier[1,2], Yannick Weiser[1,2], Stefan Richter[1,2], Ömer Bayraktar[1,2], Bastian Hacker[1,2], Conrad Rössler[1,2], Imran Khan[1,2], Andrej Krzic[3], Teresa Kopf[3], René Berlich[3], Matthias Goy[3], Daniel Rieländer[3], Fabian Steinlechner[3], Florian Kanitschar[4,5], Stefan Petscharning[4], Thomas Grafenauer[4], Ömer Bernhard[4], Christoph Pacher[4], Twesh Upadhyaya[5], Jie Lin[5], Norbert Lütkenhaus[5], Gerd Leuchs[1,2], and Christoph Marquardt[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Friedrich Alexander University Erlangen-Nürnberg, Germany — [3]Fraunhofer Institute for Applied Optics and Precision Engineering, Jena, Germany — [4]AIT Austrian Institute of Technology, Center for Digital Safety&Security, Vienna, Austria — [5]Institute for Quantum Computing and Department of Physics and Astronomy, University of Waterloo, Canada

In future metropolitan quantum key distribution (QKD) networks, point-to-point free-space links will allow to secure the communication beyond the existing but inflexible fiber backbone. For this purpose, we investigate a continuous-variable QKD system using a discrete modulation pattern in the polarization degree of freedom. We present our results obtained in an experiment over an urban 300m free-space link between the Federal Ministry of Education and Research (BMBF) and the Federal Office for Information Security (BSI) in Bonn.

QI 8.6 Mon 18:15 F442

Atom-Photon Entanglement over 101 km Telecom Fiber — •Yiru Zhou[1,2], Pooja Malik[1,2], Florian Fertig[1,2], Matthias Bock[3], Tim van Leent[1,2], Wei Zhang[1,2], Christoph Becher[3], and Harald Weinfurter[1,2,4] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany — [3]Fachrichtung Physik, Universität des Saarlandes, Saarbrücken, Germany — [4]Max-Planck-Institut für Quantenoptik, Garching, Germany

The crucial task for future quantum networks is to share entanglement over large distances. For that, quantum systems are required which provide an efficient light-matter interface, long coherence times and the possibility to connect to low-loss quantum channels.

Here we present the distribution of entanglement between an atom and a photon. Spontaneous emission of a photon at 780 nm from a single, trapped Rb-87 atom is employed to obtain entanglement between the polarization of the photon and the respective Zeeman state of the atom. Raman state transfer is used to change the encoding of the atomic qubit in a combination of F=1 & F=2 hyperfine states [1]. The reduced sensitivity to magnetic fields enables one to increase the coherence time to 7 ms. Together with efficient polarization-preserving quantum frequency conversion to telecom wavelengths minimizing the photon loss [2], we demonstrate the distribution of atom-photon entanglement over 101 km telecom fiber with a fidelity ≥70.8%.

[1] M. Körber et al., Nat. Photonics 12, 18 (2018)
[2] T. van Leent et al., Nature 607, 69-73 (2022)

QI 8.7 Mon 18:30 F442

A 3km free-space link in the munich quantum network

— •Michael Auer[1,2,3], Adomas Baliuka[1,2], Fabian Farina[3], Peter Freiwang[1,2], Swantje Kastrup[3], Hedwig Körfgen[3], Hanns Zimmermann[3], Nils gentschen Felde[3], Lukas Knips[1,2,4], Udo Helmbrecht[3], and Harald Weinfurter[1,2,4] — [1]Ludwig-Maximilians-Universität, Munich, Germany — [2]Munich Center for Quantum Science and Technology, Munich, Germany — [3]Universität der Bundeswehr München, Neubiberg, Germany — [4]Max-Planck-Institut für Quantenoptik, Garching, Germany

Quantum key distribution (QKD) enables secure key exchange, based on fundamental laws of quantum mechanics. Widespread commercial use of this technology requires robust and scalable QKD modules paired with underlying infrastructure and proper key management.

The MuQuaNet aims to build, test and operate a secure quantum communication network with multiple nodes by employing a heterogeneous framework using various manufacturers and provide this network as a transparent service to other institutes, authorities and offices.

Here, we focus on a 3km optical free-space link using a small-size, low-power, FPGA-controlled decoy-state BB84 QKD sender operating at 850nm and 100MHz. With a modulated 1550nm beacon laser, active beam stabilization using two fast steering mirrors, synchronization as well as classical communication is achieved. This will show how to integrate individual QKD links into a network or key management solution and will yield insights to long-term effects and maintainability of QKD devices outside a well controlled environment.

QI 8.8 Mon 18:45 F442

Development and characterization of a high-rate receiver for satellite-based QKD

— •Conrad Rössler[1,2], Kevin Günthner[1,2], Bastian Hacker[1,2], Gerd Leuchs[1,2], and Christoph Marquardt[1,2] — [1]Max Planck Institute for the Science of Light, Staudtstr. 2, 91058 Erlangen, Germany — [2]Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudstr. 7/A3, 91058 Erlangen, Germany

Since the famous BB84 protocol was proposed in 1984, QKD has evolved to a very mature and promising quantum technology. While classical communication is being threatened by the approach of quantum computers, QKD offers an information theoretical secure way to share a key between two parties. Our high-rate receiver is designed and tested for phase-encoded satellite-based QKD. We present the corresponding discrete variable QKD protocol as well as the concept and characterization of our photon-detection-based phase locking and time synchronization of sender and receiver.