Q 47: Quantum Information (Quantum Communication and Quantum Repeater)

Time: Thursday 10:30–12:15 Location: Q-H12

Q 47.1 Thu 10:30 Q-H12

Commercializing QKD with continuous variables — •Ulrich Eismann, Emanuel Eichhammer, Emmeran Sollner, Martin Hauer, Oliver Maurhart, and Imran Khan — KEEQuant GmbH, Gebhardtstr. 28, 90762 Fürth, Germany

QKD was proposed in the 1980s as a means of distributing cryptographic keys with information-theoretic security based on quantum physics. However it is still awaiting widespread adoption, because early protocols were based on single-photon detectors, that are not easily scalable into commercial use cases because of their elevated size and cost.

In the advent of the quantum computer threat, we aim to make QKD a commodity by relying on standard telecom components, integrated photonics and electronics. This makes QKD invisible for the end user, and hence commercially viable.

We present KEEQuant's first QKD system, highlighting some of its technical challenges. We will elaborate on our QKD scaling approach using integrated photonics. Finally, we give an overview of how cryptographic keys are handled in a telecom network with our key management system (KMS).

Q 47.2 Thu 10:45 Q-H12

Security analysis of encryption based on a quantum-provisioned root of trust — •Donika Imeri[1,2] and Ralf Riedinger[1,2] — [1]Institut für Laserphysik und Zentrum für Optische Quantentechnologien, Universität Hamburg, 22761 Hamburg, Germany — [2]The Hamburg Centre for Ultrafast Imaging, 22761 Hamburg, Germany

Over the years, quantum key distribution paved the way for physically secured communication by generating a cryptographic key via a quantum channel. Due to the loss of quantum information in this channel, the distance between two directly communicating parties is constrained. Trusted-node and quantum repeater networks could overcome this challenge, requiring expensive infrastructure. Here, we present a protocol for quantum-secured key distribution based on an information-theoretically secure root of trust provisioned over a short quantum channel. Methods like over-the-air rekeying provide the system with security similar to conventional quantum key distribution even after disconnection from the quantum channel. As no physical quantum channel is needed in the communication phase, arbitrary distances can be realized and the use of mobile end-devices is possible. For further research, this protocol can be extended to network architectures, combining flexibility and scalability with secure communication.

Q 47.3 Thu 11:00 Q-H12

Universal crosstalk decay of OAM photons in random media — •David Bachmann[1], Asher Klug[2], Mathieu Isoard[1], Vyacheslav Shatokhin[1], Giacomo Sorelli[3], Andreas Buchleitner[1], and Andrew Forbes[2] — [1]Physikalisches Institut, Albert-Ludwigs-Universität, Freiburg i. Br., Germany — [2]School of Physics, University of the Witwatersrand, Private Bag 3, Johannesburg 2050, South Africa — [3]Laboratoire Kastler Brossel, Sorbonne Université, ENS-Université PSL, Collège de France, CNRS; 4 place Jussieu, F-75252 Paris, France

High-dimensional free-space quantum communication is an active, application-oriented, research area. Most implementations of high-dimensional spatial encoding rely on photonic orbital angular momentum (OAM), but the phase fronts of the corresponding spatial modes are distorted in random media such as turbulence. Recently, it has been predicted [1] that Kolmogorov turbulence may induce crosstalk between Laguerre-Gaussian (LG) modes of opposite OAM. We confirm this behavior numerically as well as experimentally by propagating LG modes in emulated turbulence and artificial random media. Furthermore, we show that the crosstalk decay may be rescaled to a universal function of a single parameter – the ratio between the transverse correlation length of the random medium and the OAM beam's phase correlation length.

[1] Giacomo Sorelli et al., New J. Phys. 21 023003 (2019)

Q 47.4 Thu 11:15 Q-H12

Towards a nitrogen-vacancy center based quantum repeater — •Javid Javadzade[1,2], Vadim Vorobyov[1,2], Rainer Stöhr[1], Wolfgang Fischer[1], Florian Kaiser[1,2], and Jörg Wrachtrup[1,2,3] — [1]3rd Institute of Physics, University of Stuttgart, Stuttgart, Germany — [2]Institute for Quantum Science and Technology IQST, Germany — [3]Max-Planck Institute for Solid State Research, Stuttgart, Germany

The architecture of quantum repeaters is designed to solve the problem of signal fading in quantum communication lines (quantum internet) [1,2]. Single NV centers have shown their ability to be a working platform for the transmission of quantum signals [3]. Our strategy is to use NV center electron spin-photon time-bin entanglement in combination with nearby 13C spin (memory qubit) to establish communication links between repeater node and communication parties. We will present results of spin-bath characterization, where 4 suitable, weakly coupled 13C qubits were found with coupling strength in a range of 10-100 kHz. Moreover, Spin photon correlations - pre-entanglement measurement - with a fidelity of 0.8 will be shown. Additionally, the interferometer stabilization problem as long as further setup improvements will be discussed.

[1] D. Luong et al. Appl. Phys. B 122, 96 (2016). [2] C.H. Bennett & G. Brassard. Sci. 560, 7 (2014). [3] M. Pompili et al. Sci. 372, 259 (2021).

Q 47.5 Thu 11:30 Q-H12

Spectral multiplexing of individual Erbium dopants with stable transition frequency — •Alexander Ulanowski[1], Benjamin Merkel[1], and Andreas Reiserer[1,2] — [1]MPI of Quantum Optics, Garching, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Ludwig-Maximilians-Universität München, München, Germany

In a future quantum internet, coherent emitters will exchange quantum states over global distances, preferably using optical fibers. Erbium dopants exhibit an optical transition at telecommunication wavelength that would enable a low-loss transmission over long distances. To achieve an efficient spin-photon interface for single dopants, we embed a thin crystalline membrane into a tunable Fabry-Perot resonator with a finesse of $9.0(7) \cdot 10^4$ which leads up to a 70-fold Purcell enhancement. Our approach avoids the proximity of the emitters to interfaces and thus allows us to preserve the coherence up to the lifetime limit [1]. At the tail of the inhomogeneous broadening we spectrally resolve and control around 100 individual dopants with low spectral diffusion below 0.2 MHz [2]. Furthermore, at high magnetic fields some dopants reveal slow diffusion dynamics, allowing us to apply a feed-forward correction on the emission frequency and reducing the linewidth down to 0.1 MHz. Our findings enable frequency-multiplexed spin-qubit readout, control and entanglement, opening unique perspectives for the implementation of repeater nodes in a quantum network.

[1] B. Merkel et al., Phys.Rev.X 10, 041025 (2020).
[2] A. Ulanowski, B. Merkel, A. Reiserer, ArXiv:2110.09409 (2021).

Q 47.6 Thu 11:45 Q-H12

Retrieval of single photons from solid-state quantum transducers — •Tom Schmit[1], Luigi Giannelli[1,2,3], Anders Søndberg Sørensen[4], and Giovanna Morigi[1] — [1]Theoretical Physics, Department of Physics, Saarland University, 66123 Saarbrücken, Germany — [2]Dipartimento di Fisica e Astronomia "Ettore Majorana", Università di Catania, Via S. Sofia 64, 95123 Catania, Italy — [3]INFN, Sezione Catania, 95123 Catania, Italy — [4]Center for Hybrid Quantum Networks, Niels Bohr Institute, University of Copenhagen, Blegdamsvej 17, 2100 Copenhagen Ø, Denmark

Quantum networks using photonic channels require control of the interactions between the photons, carrying the information, and the elements comprising the nodes. In this work we analyze theoretically the spectral properties of an optical photon emitted by a solid-state quantum memory, which acts as a converter of a photon absorbed in another frequency range. We determine explicitly the expression connecting the stored and retrieved excitation taking into account possible mode and phase mismatch of the experimental setup. The expression we obtain describes the output field as a function of the input field for a transducer working over a wide range of frequencies, from optical-to-optical frequencies to microwave-to-optical frequencies. We apply this result to analyze the photon spectrum and the retrieval probability as a function of the optical depth for microwave-to-optical transduction.

Q 47.7 Thu 12:00 Q-H12

Indistinguishable single photons from negatively charged tin-vacancy centres in diamond — •R. Morsch[1], J. Görlitz[1], B. Kambs[1], D. Herrmann[1], P. Fuchs[1], P.-O. Colard[2], M. Markham[2], and C. Becher[1] — [1]Universität des Saarlandes, Saarbrücken 66123, Germany — [2]Element Six Global Innovation Centre, OX11 0QR, UK

For various applications in the field of quantum information processing (QIP) long-lived, stationary qubits are required that can be controlled coherently and read out optically. Quantum computing with linear optics (LOQC) moreover inherently relies on bright light-matter interfaces that provide single indistinguishable photons.

Colour centres in diamond have emerged as a promising candidate among solid state qubits. Recent experiments have shown that among those the negatively charged tin-vacancy centre (SnV−) exhibits both individually addressable spins with long coherence times and bright emission of single, close-to-transform limited photons.

By means of Hong-Ou-Mandel interferometry we here investigate the indistinguishability of single photons emitted by a single SnV-centre. We find high Hong-Ou-Mandel visibilities, being a direct measure for high indistinguishability of the single photons. We compare the experimental results with the predictions of a theoretical model and extract the magnitude of spectral diffusion potentially affecting single photon indistinguishability in the present system. Furthermore, we estimate the timescale of spectral diffusion by repeating the experiment with various delays between emission of the interfering photons.