Q 28: Quantum Information (Quantum Communication) I

Time: Wednesday 10:30–12:30 Location: Q-H12

Q 28.1 Wed 10:30 Q-H12

Propagation of orbital-angular-momentum photons across satellite-to-earth downlinks — •Jan Schreck, David Bachmann, Vyacheslav Shatokhin, and Andreas Buchleitner — Physikalisches Institut Albert-Ludwigs Universität, Hermann-Herder-Str. 3, 79104 Freiburg

Satellite-based quantum communications enable global-scale information security. Most communication systems are based on two-dimensional encoding which employs photonic spin angular momentum (SAM). Instead, photonic spatial modes endowed with orbital angular momentum (OAM) offer high-dimensional encoding, which enhances the channel capacity, and the security of quantum key distribution (QKD) protocols. However, OAM is very fragile with respect to turbulence-induced phase front distortions.

In this talk, we discuss a faithful numerical method to account for atmospheric effects on OAM beams for a broad range of turbulence conditions. We then present our simulations of beam propagation through slant atmospheric channels, and identify turbulence regimes where high-dimensional communication using OAM beams is possible.

Q 28.2 Wed 10:45 Q-H12

Nondestructive detection of photonic qubits — •Pau Farrera, Dominik Niemietz, Stefan Langenfeld, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Garching, Germany

Qubits encoded in single photons are very useful to distribute quantum information over remote locations, but at the same time are also very fragile objects. The loss of photonic qubits is actually the main limitation in the maximum reachable quantum communication distance. In this context, the nondestructive detection of photonic qubits is a great scientific challenge that can help tracking the qubit transmission and mitigate the loss problem. Such a detector is envisioned to improve loss-sensitive qubit measurements, facilitate protocols in which distributed tasks depend on the successful dissemination of photonic qubits, and also enable certain quantum key distribution attacks. We recently implemented such a detector with a single atom coupled to two crossed fiber-based optical resonators, one for qubit-insensitive atom-photon coupling and the other for atomic-state detection. We achieve a nondestructive detection efficiency of 79(3)% conditioned on the survival of the photonic qubit, a photon survival probability of 31(1)%, and we preserve the qubit information with a fidelity of 96.2(0.3)%. To illustrate the potential of our detector we show that it can provide an advantage for long-distance entanglement and quantum-state distribution, resource optimization via qubit amplification, and detection-loophole-free Bell tests.

Q 28.3 Wed 11:00 Q-H12

Improved Bell-state Measurements with Linear Optics — •Matthias Bayerbach, Simone d'Aurelio, and Stefanie Barz — Institute for Functional Matter and Quantum Technologies & IQST, University of Stuttgart, 70569 Stuttgart, Germany

Bell-state measurements play a key role in many quantum communication and computing applications like quantum repeaters or measurement-device-independent quantum key distribution. Standard Bell-state measurements using linear optics, however, can only distinguish two of the four Bell states, limiting the efficiency of all applications to 50 %. In this talk, we present the realization of a scheme [1], which can distinguish Bell states with more than 50 % success probably by utilising interference between the Bell state and an ancillary N00N state in a linear-optical circuit. Measuring the photon-number distribution of the output allows then identifying the respective Bell state.

[1] F. Ewert and P. van Loock, Phys. Rev. Lett. 113, 140403 (2014)

Q 28.4 Wed 11:15 Q-H12

Temporal mode decoding with a multi-output quantum pulse gate — •Laura Serino, Jano Gil-Lopez, Werner Ridder, Raimund Ricken, Christof Eigner, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Department of Physics, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburgerstr. 100, D-33098 Paderborn, Germany

Quantum key distribution (QKD) is a secure communication method that allows two parties to encrypt a message through a random secret key encoded in the degrees of freedom of photons. Notably, high-dimensional (HD) QKD is characterized by a higher level of security and efficiency with respect to its binary counterpart, and temporal modes (TMs) represent a convenient encoding basis.

In this work, we demonstrate a multi-output quantum pulse gate (mQPG), a device based on dispersion-engineered sum-frequency generation in periodically poled lithium niobate waveguides which can serve as a receiver for HD QKD. The mQPG allows one to project an input state at the same time onto all the elements of a HD TM basis and map the result of each projection onto a distinct output frequency.

To achieve multi-channel operation, the poling structure is engineered to generate multiple phase-matching peaks. Appropriate shaping of the pump spectrum maps each TM to one phase-matching peak and hence output frequency. A time-of-flight measurement achieves frequency-demultiplexing of the output beam, mapping the input TM to the arrival time of the photon. As proof of principle, we show a five-dimensional detector tomography obtained with this method.

Q 28.5 Wed 11:30 Q-H12

A multi-rail random-access optical memory in hot Cs with 4 μs lifetime — •Leon Messner[1,2,3], Elizabeth Robertson[2,3], Luisa Esguerra[2,3], Kathy Lüdge[4], and Janik Wolters[2,3] — [1]Institut für Physik, Humboldt-Universität zu Berlin, Newtonstr. 15, 12489 Berlin, Germany — [2]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institute of Optical Sensor Systems, Rutherfordstr. 2, 12489 Berlin, Germany — [3]Technische Universität Berlin, Institut für Optik und Atomare Physik, Str. des 17 Juni 135, 10623 Berlin, Germany — [4]Institute of Physics, Technische Universität Ilmenau, Weimarer Str. 25, 98693 Ilmenau, Germany

Random-access quantum memories (RAQMs) are considered essential in near-term quantum communication networks [1] and computing architectures. In contrast to demonstrated RAQMs in cold ensembles or single atoms, this work demonstrates an optical memory in hot Cs vapor, that is comparatively easy to miniaturize and integrate into ground and space-borne devices. Using an acousto-optic deflector (AOD) to deflect the co-propagating signal and control pulses in an EIT memory setup [2], we show a multi-rail optical memory with random access using four parallel rails in a single Cs vapor cell. Extending the number of rails is feasible with specialized AODs and a 2-dimensional lattice of rails. The 1/e lifetime of our memory was found to be 4 μs, limited by magnetic noise, and we achieved rail dependent internal memory efficiencies of between 33% and 42%.

[1] Wallnöfer, J. et al., arXiv:2110.15806 [quant-ph] (2021)
[2] Wolters, J. et al., PRL, **119**, 060502 (2017)

Q 28.6 Wed 11:45 Q-H12

Device-Independent Quantum Key Distribution between Distant Users — •Tim van Leent[1,2], Wei Zhang[1,2], Kai Redeker[1,2], Robert Garthoff[1,2], Florian Fertig[1,2], Sebastian Eppelt[1,2], Rene Schwonnek[3,4], Wenjamin Rosenfeld[1,2,7], Valerio Scarani[5,6], Charles Lim[3,5], and Harald Weinfurter[1,2,7] — [1]Fakultät für Physik, Ludwig-Maximilians-Universität, Munich, Germany — [2]Munich Center for Quantum Science and Technology (MCQST), Munich, Germany — [3]Department of Electrical & Computer Engineering, National University of Singapore, Singapore — [4]Naturwissenschaftlich-Technische Fakultät, Universität Siegen, Germany — [5]Centre for Quantum Technologies, National University of Singapore, Singapore — [6]Department of Physics, National University of Singapore, Singapore — [7]Max-Planck-Institut für Quantenoptik, Garching, Germany

Device-independent quantum key distribution (DIQKD) is the art of establishing secure keys over untrusted channels using untrusted devices, thereby harnessing the ultimate quantum advantage for secure communications. Here we present a proof-of-concept DIQKD experiment between two users at locations 400 meters apart [1]. For this, we employ heralded entanglement between two remote single-atom quantum memories to verify the security of the generated key with a Bell-test [2]. We show that—based on asymptotic security estimates—our apparatus establishes secure keys in a fully device-independent way.

[1] W. Zhang et al., arXiv:2110.00575 (2021)
[2] W. Rosenfeld et al., Phys. Rev. Lett. **119**, 010402 (2017)

Q 28.7 Wed 12:00 Q-H12

Employing Atomically Thin Single-Photon Sources for Tests of Quantum Key Distribution — •Timm Gao[1], Martin v. Helversen[1], Carlos Anton-Solanas[2], Christian Schneider[2], and Tobias Heindel[1] — [1]Institut für Festkörperphysik, Technische Universität Berlin, 10623 Berlin, Germany — [2]Institut für Physik, Carl von Ossietzky Universität Oldenburg, 26111 Oldenburg, Germany

Quantum light sources are considered key building blocks for future quantum communication networks. In recent years, atomic monolayers of transition metal dichalcogenides (TMDCs) emerged as a promising material platform for the development of compact quantum light sources. In this work, we evaluate for the first time the performance of a single-photon source (SPS) based on a strain engineered WSe_2 monolayer [1] for applications in quantum key distribution (QKD). Employed in a QKD-testbed emulating the BB84 protocol, an antibunching of $g^{(2)}(0) = 0.127 \pm 0.001$ and a raw key rate of up to (66.95 ± 0.10)kHz make this source competitive with previous SPS based QKD experiments using quantum dot based SPSs. Furthermore, we exploit routines for the performance optimization previously applied to quantum dot based single-photon sources [2]. Our work represents an important step towards the application of TMDC-based devices in quantum technologies.

[1] L. Tripathi et al., ACS Photonics 5, 1919-1926 (2018)
[2] T. Kupko et al., npj Quantum Information 6, 29 (2020)

Q 28.8 Wed 12:15 Q-H12

A Quantum Key Distribution Testbed using a Plug&Play Telecom-Wavelength Single-Photon Source — •Timm Gao[1], Lucas Rickert[1], Felix Urban[1], Jan Grosse[1], Nicole Srocka[1], Sven Rodt[1], Anna Musiał[2], Kinga Żołnacz[3], Paweł Mergo[4], Kamil Dybka[5], Wacław Urbańczyk[3], Grzegorz Sęk[2], Sven Burger[6], Stephan Reitzenstein[1], and Tobias Heindel[1] — [1]Institute of Solid State Physics, Technical University Berlin, 10623 Berlin, Germany — [2]Department of Experimental Physics, Wrocław University of Science and Technology, 50-370 Wrocław, Poland — [3]Department of Optics and Photonics, Wrocław University of Science and Technology, 50-370 Wrocław, Poland — [4]Institute of Chemical Sciences, Maria Curie Sklodowska University, 20-031 Lublin, Poland — [5]Fibrain Sp. z o.o., 36-062 Zaczernie, Poland — [6]Zuse Institute Berlin, 14195 Berlin, Germany

We report on quantum key distribution (QKD) tests using a 19-inch benchtop single-photon source at 1321 nm based on a fiber-pigtailed quantum dot (QD) integrated into a Stirling cryocooler. Emulating the polarization-encoded BB84 protocol, we achieve an antibunching of $g^{(2)}(0) = 0.10 \pm 0.01$, a raw key rate of up to 4.72 ± 0.13 kHz. Exploiting optimized temporal filters [1] in the asymptotic limit a maximum tolerable loss of 23.19 dB can be achieved. Our study represents an important step forward in the development of fiber-based quantum-secured communication networks exploiting sub-Poissonian quantum light sources.

[1] T. Kupko et al., arXiv.2105.03473 (2021)