Q 31: Quantum Networks, Repeaters, and QKD III (joint session Q/QI)

Time: Wednesday 11:00–13:00 Location: AP-HS

Q 31.1 Wed 11:00 AP-HS

Diamond Membrane with strained SiV color centers coupled to a fabry perot microcavity — •Florian Feuchtmayr[1], Robert Berghaus[1], Selene Sachero[1], Gregor Bayer[1], Julia Heupel[2], Tobias Herzig[3], Jan Meijer[3], Cyril Popov[2], and Alexander Kubanek[1] — [1]Institut für Quantenoptik Universitat Ulm — [2]Institute of Nanostructure Technologies and Analytics, Center for Interdisciplinary Nanostructure Science and Technology, University of Kassel — [3]Division of Applied Quantum Systems, Felix Bloch Institute for Solid State Physics, University Leipzig

Group IV color centers in diamond, such as silicon vacancy (SiV), are promising for quantum optics because of their optical transitions, spin access, and good coherence properties. SiV centers typically require millikelvin temperatures, but increasing the ground state splitting improves coherence, allowing operation at higher temperatures. Here, we demonstrate the integration of a single-crystal diamond membrane into a high-finesse microcavity (F = 3000), achieving significant lifetime shortening with a Purcell factor of 2.2 in a liquid helium atmosphere. Absorption and strain spectroscopy confirm enhanced ground-state splitting, paving the way for a spin-photon interface.

Q 31.2 Wed 11:15 AP-HS

Indistinguishability of quantum-dot molecule based single photon sources — •Steffen Wilksen[1], Alexander Steinhoff[2], and Christopher Gies[1] — [1]Institut für Physik, Fakultät V, Carl von Ossietzky Universität Oldenburg — [2]Institut für theoretische Physik, Universität Bremen

Quantum-dot molecules (QDMs) consist of two self-assembled semiconductor quantum dots on top of each other separated by a thin tunnelling barrier, allowing charge carriers to tunnel between dots and form delocalized states. Due to their high tunability and rich level scheme, they provide a promising entanglement-generation platform for use in quantum communication and measurement-based quantum computing.

A key property of the emitted individual photons is their indistinguishability. Due to interaction with the environment during the emission process, the photons lose their coherence and ability to interfere with one another. These influences are of particular relevance in semiconductor systems, and to minimize their effects, one aims to reduce external noise while decreasing the emission time using optical cavities.

We investigate the indistinguishability of single photons emitted from a QDM solving both the independent boson model and the Jaynes-Cummings model using both analytic and numerical approaches. We extend the independent-boson model to account for a more realistic behaviour of phonons while keeping it exactly solvable. When a cavity is included, we use exact diagonalization to calculate the attainable indistinguishability.

Q 31.3 Wed 11:30 AP-HS

Large-Range Tuning and Stabilization of the Optical Transition of Diamond Tin-Vacancy Centers by In-Situ Strain Control — •Julia M. Brevoord[1], Leonardo G. C. Wienhoven[1], Nina Codreanu[1], Tetsuro Ishiguro[1,2], Elvis van Leeuwen[1], Mariagrazia Iuliano[1], Lorenzo DeSantis[1], Christopher Waas[1], Hans K.C. Beukers[1], Tim Turan[1], Carlos Errando-Herranz[1,3], Kenichi Kawaguchi[2], and Ronald Hanson[1] — [1]QuTech and Kavli Institute of Nanoscience, Delft University of Technology, Delft 2628 CJ, Netherlands — [2]Quantum Laboratory, Fujitsu Limited, 10-1 Morinosato-Wakamiya, Atsugi, Kanagawa 243-0197, Japan — [3]Department of Quantum and Computer Engineering, Delft University of Technology, Delft 2628 CJ, Netherlands

Quantum technologies, such as quantum networking based on photonic links rely on entanglement generation via indistinguishable photons from the qubits. The tin-vacancy (SnV) center in diamond has emerged as a promising platform, offering good optical and spin properties. However, variations in local strain and electronic environments have posed significant challenges to photon indistinguishability, limiting scalability. In this work, we achieve large-range optical frequency tuning and active stabilization of SnV centers using microelectromechanical strain control integrated into photonic waveguide devices. These results represent a critical step forward in overcoming scalability challenges and enabling the development of robust, large-scale quantum networks.

Q 31.4 Wed 11:45 AP-HS

Feasibility of Long-Distance Multi-Photon Interference in Satellite-Based Quantum Networks — •Baghdasar Baghdasaryan[1], Karen Lozano Méndez[2], Meritxell Cabrejo Ponce[2], Stephan Fritzsche[3,4], and Fabian Steinlechner[1,2] — [1]Institut für Angewandte Physik, Jena, Germany — [2]Fraunhofer Institute for Applied Optics and Precision Engineering IOF, Jena, Germany — [3]Theoretisch-Physikalisches Institut, Jena, Germany — [4]Helmholtz-Institut, Jena, Germany

Interference of multi-photon states involves the interaction of two photons on a beam splitter, where the photons must be indistinguishable across all degrees of freedom. Temporal indistinguishability occurs when the photons can not be distinguished based on their arrival times. This can be achieved with time-synchronized pulsed photon sources by controlling photon generation times. However, time synchronization is challenging in satellite-based communication systems due to satellite motion. A promising alternative is the use of photon sources with continuous emission. Temporally indistinguishable photons can be post-selected by carefully measuring the respective arrival times. While post-selection eliminates the need for active time synchronization, the finite resolution of detectors limits the precision of time-resolved detection. Here, we examine the impact of limited detector resolution on the efficiency of multi-photon interference with a focus on entanglement swapping. We estimate the maximum achievable entangled photon pair rate by optimizing the performance of the source and analyzing potential losses in a Earth-satellite link.

Q 31.5 Wed 12:00 AP-HS

Towards compensation of component imperfections in polarization-based BB84 QKD transmitters — •Silas Eul[1,2,3], Joost Vermeer[1,3], Domenico Paone[2], Ömer Bayraktar[1,3], Julian Struck[2], and Christoph Marquardt[1,3] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstr. 7, 91058 Erlangen, Germany — [2]Tesat-Spacecom GmbH & Co. KG, Gerberstr. 49, 71522 Backnang, Germany — [3]Max Planck Institute for the Science of Light, Staudtstr. 2, 91058 Erlangen, Germany

Quantum key distribution systems typically rely on components that are highly polarization-dependent, such as polarization splitters and waveplates, as well as components that are intended to keep the polarization intact, such as fibers or non-polarizing beam splitters. In a real case scenario, there are no perfect components and the polarization errors generally increase when using smaller components, for example when transitioning from free space to fiber-based to photonic integrated circuit-based setups. In this work the influence of these components is discussed and possibilities to compensate, minimize or bypass these problems are highlighted. Here we focus on transmitters for polarization-based BB84 for free space and satellite applications.

Q 31.6 Wed 12:15 AP-HS

Detection of Intercept-Resend Blinding Attacks for Quantum Key Distribution with Waveguide-Integrated Superconducting Nanowire Single-Photon Detectors — •Connor A. Graham-Scott[1,3,4], Roland Jaha[2,3,4], Konstantin Zaitsev[5], Polina Acheva[5], Robin Terhaar[2,3,4], Wolfram Pernice[2,3,4], Vadim Makarov[5], and Carsten Schuck[1,3,4] — [1]Department of Quantum Technologies, University of Münster, Germany — [2]Kirchhoff-Institute for Physics, University of Heidelberg, Germany — [3]Center for Nanotechnology, Münster, Germany — [4]Center for Soft Nanoscience, Münster, Germany — [5]Quantum Hacking and Certification Lab, Vigo Quantum Communication Center, Spain

Quantum key distribution (QKD) offers secure communication via quantum mechanics but is vulnerable to eavesdroppers exploiting single-photon detectors with high-intensity optical pulses to blind and control them. Superconducting nanowire single-photon detectors (SNSPDs) can be attacked by manipulating the decaying-edge of the signal around a comparator trigger voltage, enabling quantum key replication.

We demonstrate that waveguide-integrated SNSPDs counteract such attacks by inducing a permanent resistive latching state above single-photon optical intensities without compromising performance. Testing devices with kinetic inductance from 625nH to 41nH revealed that lower-inductance devices (41nH) latched under multi-photon pulses, exposing eavesdropping attempts. This establishes waveguide-integrated SNSPDs as a secure solution for eavesdropping in QKD.

Q 31.7 Wed 12:30 AP-HS

QKD with Single Photons from Semiconductor Quantum Dots — •Joscha Hanel[1], Jingzhong Yang[1], Jipeng Wang[1], Vincent Rehlinger[1], Zenghui Jiang[1], Frederik Benthin[1], Tom Fandrich[1], Jialiang Wang[1], Fabian Klingmann[2], Raphael Joos[3], Stephanie Bauer[3], Sascha Kolatschek[3], Ali Hreibi[4], Eddy Rugeramigabo[1], Michael Jetter[3], Simone Portalupi[3], Michael Zopf[1,5], Peter Michler[3], Stefan Kück[4], 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 present a BB84 QKD system based on single photons from a quantum dot (QD) source embedded into a circular bragg grating (CBG). The QD emits directly into the telecom C-band with high brightness and a low $g^{(2)}(0)$ of 0.7%. The encoding scheme features a phase modulator in a Sagnac configuration to inscribe four polarization states at a high modulation speed of 76MHz and with a low quantum bit error rate (QBER) on the order of 1%. We demonstrate the QKD capabilities of the system over increasing transmission distances in fiber, utilizing live polarization drift compensation and software-based synchronization, and show that it is fit for use on an intercity scale.

[1] Yang, J. et al., https://doi.org/10.1038/s41377-024-01488-0
[2] Nawrath et al., https://doi.org/10.1002/qute.202300111

Q 31.8 Wed 12:45 AP-HS

Photonic-integrated components for satellite-based QKD aboard the launched mission QUBE — •Ömer Bayraktar[1,2], Jonas Pudelko[1,2], Joost Vermeer[1,2], and Christoph Marquardt[1,2] — [1]Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Max Planck Insitute for the Science of Light, Erlangen, Germany

Satellite-based quantum key distribution (SatQKD) presents a promising advancement in secure communications. CubeSats, in particular, offer a cost-effective means for conducting QKD over long distances; however, they necessitate the creation of highly integrated optical systems. Within the framework of the QUBE mission, we have developed an integrated sender for modulated weak coherent states and an integrated quantum random number generator. Following the successful launch of the QUBE satellite in August 2024, we report on the progress achieved and the challenges encountered in one of only a few missions testing components for SatQKD in space.