HL 47: Focus Session: Quantum Technologies in Deployed Systems II

Recent advancements in quantum cryptography, quantum computing, and quantum sensing are driving researchers to develop a universal quantum network*known as the quantum internet, which will enable secure connections among quantum computers, as well as to networks of quantum sensors, through quantum cryptography. Building a functional quantum internet is one of the most ambitious goals in quantum technology for the coming decades.

The focus sessoin aims to provide a comprehensive overview of the corresponding platforms and advances in quantum technologies, and is organized by Simone L. Portalupi (U. Stuttgart), Michal Vyvlecka (U. Stuttgart) and Michael Zopf (U. Hannover).

Time: Thursday 9:30–12:30 Location: H17

Invited Talk HL 47.1 Thu 9:30 H17

Quantum-Dot Quantum Light Sources in Deployed Systems — •Peter Michler — Institute for Semiconductor Optics and Functional interfaces, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Stuttgart, Germany

Quantum photonic networks require sources of single, indistinguishable and entangled photon pairs with high brightness [1]. Semiconductor quantum dots (QDs) hold great promise to meet these requirements. In many foreseen implementations of quantum photonic networks, full-photonic quantum teleportation is a cornerstone, and the photons must be able to propagate over long distances in silica fibers with limited absorption and wave packet dispersion. Photons in the so-called telecom bands will experience minimum absorption (C-band) and dispersion (O-band). Moreover, from a practicable point of view, portable rack single- and entangled photon sources are advantageous in deployed systems.

In this talk, we report on the performance of quantum-dot quantum light sources in deployed fibers [2], and demonstrate quantum teleportation with telecom photons from remote quantum emitters [3]. Moreover, QKD with entangled photons is demonstrated in deployed fibers and the performance of a QD based portable rack single- and entangled photon source, which can be operated down to 4 K, is presented.

References: [1] R. Joos et al., Nano Letters 24, 8626 (2024) [2] T. Strobel et al., Optica Quantum 2, 274 (2024) [3] T. Strobel et al., arXiv:2411.12904 (2024)

Invited Talk HL 47.2 Thu 10:00 H17

Field test of semiconductor quantum light sources — •Fei Ding — Leibniz University Hannover, Germany

Semiconductor quantum dots (QDs) are among the most promising quantum light sources, with the potential to revolutionize quantum communication research. For instance, utilizing on-demand single photons and entangled photons in quantum key distribution (QKD) protocols can significantly enhance security and increase the maximum tolerable loss. However, several critical challenges must be addressed to bridge the gap between laboratory experiments and long-distance field tests using QDs. In this talk, I will first review our work over the past years on QD-based single-photon and entangled-photon sources. Following that, I will present our recent field tests of single photon transmissions over a 79 km link between Hannover and Braunschweig, with 25.49 dB loss, equivalent to 130 km in direct-connected optical fiber.

Invited Talk HL 47.3 Thu 10:30 H17

Quantum dot based quantum communication in urban networks — •Rinaldo Trotta — Sapienza University of Rome, Italy

The last two decades have witnessed an impressive progress in the development of single and entangled photon sources based on quantum dots. It has now arrived the moment to explore their full potential in urban quantum-communication scenarios.

In this talk, I will first discuss how single and entangled photons generated by quantum dots can be used to implement advanced quantum communication protocols in a controlled laboratory environment. Then, I will show our efforts towards the construction of a hybrid quantum network, harnessing both fibre and free-space links, within the University campus in the centre of Rome. Finally, I will present field demonstrations of point-to-point entanglement-based quantum key distribution and three-node quantum teleportation with dissimilar quantum dots. A discussion on future challenges and perspectives will conclude the talk.

15 min. break

Invited Talk HL 47.4 Thu 11:15 H17

Quantum communication protocols over a 14-km urban fiber link — •Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken, Germany

Quantum communication over urban telecom fibers poses challenges such as environmentally induced polarization fluctuations and lossy splices. We report on the characterization and operation of a 14-km long fiber link across Saarbrücken for quantum communication. The dark fiber has underground and overground sections and $\sim 9\,\mathrm{dB}$ attenuation. We stabilize its polarization with $> 99\%$ process fidelity up to 60 s. For implementing quantum communication protocols we employ a $^{40}Ca^+$ single-ion quantum memory, an ion-resonant entangled photon-pair source, and quantum frequency conversion.

We distribute photonic entanglement without significant fidelity degradation. Using heralded absorption of one photon of the entangled pair, we also demonstrate atom-to-photon quantum state teleportation over the fiber link with $\sim 84\%$ average fidelity [1].

In a laboratory experiment we also realize a quantum repeater cell based on two $^{40}Ca^+$ ions that are asynchronously entangled with their emitted photons. By entanglement swapping via a Mølmer-Sørensen quantum gate on the ions, which are located in the same trap, we generate photon-photon entanglement with $\sim 76\%$ average fidelity [2].

[1] S. Kucera et al., npj Quantum Information **10**, 88 (2024)
[2] M. Bergerhoff et al., Phys. Rev. A **110**, 032603 (2024)

HL 47.5 Thu 11:45 H17

Quantum cryptography at deployed communication networks with quantum dots at telecommunication wavelengths — •Anna Friederike Köhler[1], Tim Strobel[1], Michal Vyvlecka[1], Raphael Joos[1], Ilenia Neureuther[1], Timo Schnieber[1], Tobias Bauer[2], Marlon Schäfer[2], Nand Lal Sharma[3], Weijie Nie[3], Ghata Bhayani[3], Caspar Hopfmann[3], Simone Luca Portalupi[1], Christoph Becher[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen (IHFG), Center for Integrated Quantum Science and Technology (IQST) and SCoPE, University of Stuttgart, Allmandring 3, 70569 Stuttgart, Germany — [2]Fachrichtung Physik, Universität des Saarlandes, Campus E2.6, 66123 Saarbrücken, Germany — [3]Institute for Integrative Nanosciences, Leibniz IFW Dresden, Helmholtzstraße 20, 01069 Dresden, Germany

Quantum cryptography leverages quantum effects to achieve unprecedented security. Quantum dot-based nonclassical light sources hold a promise for efficient cryptographic applications, offering on-demand generation of entangled photon pairs with high brightness and negligible multi-photon contribution. These features enable high-speed quantum communication while minimizing security risks. In this work, we demonstrate the BBM92 quantum key distribution protocoll using a GaAs quantum dot source to produce high-fidelity entangled photon pairs. Frequency conversion to telecommunication wavelengths is implemented to enhance transmission efficiency in a deployed intracity silica-based fiber network.

HL 47.6 Thu 12:00 H17

Experimental Quantum Strong Coin Flipping using a Deterministic Single-Photon Source — Daniel Vajner[1], •Koray Kaymazlar[1], Fenja Drauschke[2], Lucas Rickert[1], Martin von Helversen[1], Shulun Li[3], Zhichuan Niu[3], Anna Pappa[2,4], and Tobias Heindel[1] — [1]Institute of Solid State Physics, Technische Univeristät Berlin, Germany — [2]Electrical Engineering and Computer Science Department, Technische Univeristät Berlin, Germany — [3]Institute of Semiconductors, Chinese Academy of Sciences, Beijing, China — [4]Fraunhofer Institute for Open Communication Systems - FOKUS, Technical University Berlin, Germany

Strong coin flipping (SCF) is a fundamental cryptographic protocol allowing two distrustful parties to agree on randomly generated bit. In this work, we report the first implementation of a quantum strong coin flipping protocol that yields a quantum advantage compared to both its classical counterpart and an implementation using weak coherent pulses.

The quantum advantage is enabled by employing a state-of-the-art deterministic single-photon source based on a quantum dot embedded in a high-Purcell microcavity. Using a fiber-based electro-optic modulator (EOM) in single-pass configuration in combination with a self-built arbitrary waveform generator we realize fast dynamic, random polarization-state encoding at 80 MHz clock-rate.

Our QSCF implementation enables a coin flipping rate of 1.5 kHz and an average quantum bit error ratio (QBER) below 3%, sufficient to realize a quantum advantage.

HL 47.7 Thu 12:15 H17

Establishing a Quantum Local Area Network in Berlin City using Deterministic Quantum Light Sources — •Martin von Helversen[1], Lucas Rickert[1], Anne Rohwäder[1], Kinga Zolnacz[2], Koray Kaymazlar[1], Daniel Vajner[1], Anna Musial[3], Grzegorz Sek[3], Hanqing Liu[4], Zhichuan Niu[4], and Tobias Heindel[1] — [1]Institute of Solid State Physics, Technical University Berlin, Berlin, Germany — [2]Department of Optics and Photonics, Wroclaw University of Science and Technology, Wroclaw, Poland — [3]Department of Experimental Physics, Wroclaw University of Science and Technology, Wroclaw, Poland — [4]Institute of Semiconductors, Chinese Academy of Sciences, Beijing, China

Applications of quantum information enabled by solid-state quantum light sources currently witness the transition from laboratory proof-of-concept to field-experiments. In this contribution we present our recent progress in establishing a quantum local area network at the Campus Charlottenburg of TU Berlin. We show results of an actively stabilized free-space optical link with an effective length of 400 m and an end-to-end transmission of >70%. In addition, we operate a fiber-link between two buildings consisting of 6x 650 m of dark optical fiber. Moreover, we discuss the deployment of mobile deterministic single-photon sources based on compact cryocoolers and fiber-pigtailed quantum dot microcavities [FC-CBG] and evaluate the suitability for implementations of different types of cryptographic primitives. [1] Rickert, Lucas, et al., arXiv:2409.08982 (2024) [2] Rickert, Lucas, et al., arXiv:2408.02543 (2024).