Q 59: QuanTour V – Protocols

Inspired by QuanTour, the traveling quantum-dot light source, the sessions QuanTour I-V focus on the physics of quantum light generation in solid-state systems and applications in quantum networks.

Time: Thursday 14:30–16:30 Location: P 7

Invited Talk Q 59.1 Thu 14:30 P 7

High-Speed Quantum Key Distribution using Single Photons from Defects in Hexagonal Boron Nitride — Furkan Ağlarci[1], Ömer S. Tapşin[1], Çağlar Samaner[1], Serkan Paçal[1], and •Serkan Ateş[1,2] — [1]Department of Physics, Izmir Institute of Technology, Izmir, Türkiye — [2]Faculty of Engineering and Natural Sciences, Sabanci University, Tuzla, Istanbul, Türkiye

We present an experimental demonstration of free-space Quantum Key Distribution (QKD) utilizing single photons generated from optically active defects in hexagonal boron nitride (hBN) operating at room temperature (RT). In our implementation of the B92 protocol, we successfully integrated the hBN single-photon source (SPS) with a resonant electro-optic modulator, enabling dynamic polarization encoding at a 40 MHz clock rate. This high-speed operation yielded a sifted key rate of 17.5 kbps and a secure key rate (SKR) of 7 kbps with a Quantum Bit Error Rate of 6.49%, representing one of the highest reported SKRs for a RT-SPS with active polarization modulation. We benchmark this performance against other quantum emitters and analyze the potential of hBN defects in a hypothetically secured BB84 framework. We show that with achievable improvements, such as microcavity coupling, the source has the potential to reach an SKR in the Mbps range. This work highlights the versatility and maturity of hBN defects as bright, RT-SPS, paving the way for practical, high-speed, and miniaturized quantum communication systems, including future space-based QKD missions.

Q 59.2 Thu 15:00 P 7

GHz-clocked Single-photon Quantum Key Distribution in the Telecom C-band — •Mareike Lach[1], Koray Kaymazlar[1], Robert B. Behrends[1], Lucas Rickert[1], Martin von Helversen[1], Jochen Kaupp[2], Yorick Raum[2], Tobias Huber Loyola[2,3], Sven Höfling[2], Andreas Pfenning[2], and Tobias Heindel[4] — [1]Institute of Physics and Astronomy, Technische Univeristät Berlin — [2]Technische Physik, Physikalisches Institut and Würzburg-Dresden Cluster of Excellence — [3]Karlsruher Institut für Technologie, Institute of Photonics and Quantum Electronics — [4]Department for Quantum Technology, Univeristät Münster

High speed operation is one of the most desired properties for implementations of quantum key distribution (QKD). This requires however the generation and state-preparation of photonic qubits at high speed. Here, we report on a QKD system based on the BB84 protocol that operates at GHz clock-rates using a highly Purcell-enhanced single-photons source emitting in the telecom C-band. We use a laser with a repetition rate of 2.5 GHz to pump the quantum dot source and prepare the polarization states fot the protocol using a customized fiber-based electro-optic modulator (EOM) controlled by an arbitrary waveform generator (AWG) using the trigger output of the pump laser as common clock. Our results show that our system performs the BB84 protocol succesfully with a quantum bit error ratio (QBER) around 5 % at these unprecendeted high clock-rates.

Q 59.3 Thu 15:15 P 7

Deployed entanglement-based BBM92 quantum key distribution using frequency-converted photons emitted by a quantum dot — •Michal Vyvlecka[1], Raphael Joos[1], Benjamin Breiholz[1], Aurélien Marmasse[1], Ilenia Neureuther[1], Timo Schnieber[1], Anna Frederike Köhler[1], Tim Strobel[1], Tobias Bauer[2], Marlon Schäfer[2], Nand Lal Sharma[3], Caspar Hofmann[3], Simone Luca Portalupi[1], Christoph Becher[2], and Peter Michler[1] — [1]Institut für Halbleiteroptik und Funktionelle Grenzflächen, Center for Integrated Quantum Science and Technology (IQST) and SCoPE, 70569 Stuttgart, Germany — [2]Fachrichtung Physik, 66123 Saarbrücken, Germany — [3]Institute for Integrative Nanosciences, 01069 Dresden, Germany

We implemented an entanglement-based BBM92 quantum key distribution (QKD) protocol over approximately 700 m across the university campus buildings using the existing deployed fiber network. The entangled-photon pair at wavelength of 780 nm was emitted by an epitaxially grown droplet-etched GaAs quantum dot (QD) embedded in a dielectric antenna. The QD was excited via two-photon excitation using a pulsed laser that emits 10 ps pulses at 779 nm with a 380 MHz repetition rate. To minimize losses in silica fibers, we employed bidirectional, polarization-conserving quantum frequency conversion to shift the QD emission to a telecom wavelength. We achieved stable QKD operation for more than 10 hours, with a raw key rate exceeding 200 Hz and a quantum bit error rate below 4.5 %. After error correction and privacy amplification, we distilled a secure key at a rate of 100 Hz.

Q 59.4 Thu 15:30 P 7

Experimental Quantum Strong Coin Flipping - An Application of QTorch — •Koray Kaymazlar[1], Daniel Vajner[1], Fenja Drauschke[2], Lucas Rickert[1], Martin von Helversen[1], Shulun Li[3], Zhichuan Niu[3], Anna Pappa[2], and Tobias Heindel[4] — [1]Institute of Physics and Astronomy, 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]Department for Quantum Technology, University of Münster, Germany

Strong coin flipping is a fundamental cryptographic protocol allowing two distrustful parties to agree on randomly generated bits. We report the first implementation of a quantum strong coin flipping using single photons and demonstrate a quantum advantage compared to both classical protocols and implementations using weak coherent pulses [1]. The quantum advantage is enabled by employing a state-of-the-art deterministic single-photon source from the same family of the one used in QuanTour outreach project based on a quantum dot embedded in a high-Purcell microcavity. Our QSCF implementation, operating at an 80 MHz clock-rate enables a coin flipping rate of 1.5 kHz and an average QBER below 3%, sufficient to realize a quantum advantage. [1] D. A. Vajner, K. Kaymazlar, F. Drauschke, L. Rickert, M. von Helversen, H. Liu, S. Li, H. Ni, Z. Niu, A. Pappa, T. Heindel, Single-Photon Advantage in Quantum Cryptography Beyond QKD, arXiv:2412.14993 (2024)

Q 59.5 Thu 15:45 P 7

Benchmarking quantum key distribution by mixing single photons and laser light — •Yann Portella[1], Petr Steindl[1], Juan Rafael Álvarez[1], Tim Hebenstreit[2], Aristide Lemaître[1], Martina Morassi[1], Niccolo Somaschi[3], Loïc Lanco[1], Filip Rozpedek[4], Pascale Senellart[1], and Dario A. Fioretto[1,3] — [1]Centre de Nanosciences et de Nanotechnologies, Université Paris-Saclay, CNRS, Palaiseau, France — [2]Max Planck Institute for the Science of Light, Erlangen, Germany — [3]Quandela SAS, Massy, France — [4]College of Information and Computer Science, University of Massachusetts Amherst, Amherst, Massachusetts, USA

Quantum key distribution stands out as a major application of quantum technologies, alongside quantum computing and quantum sensing. Many protocols require single photons, often approximated by dim laser pulses. Here, we propose a hybrid approach where the information is encoded with an incoherent mixture of single photons generated by a micropillar-embedded quantum dot and laser pulses. We show that there is an optimal mixture at any distance maximizing the secret key rate, benefiting both from the long distance scaling of single photons and high rate at short distance of laser light. This provides a flexible technology compensating for limited collected brightnesses of single-photon sources as well as a thorough investigation of advantage scenarios for single-photon and hybrid statistics. We highlight an efficiency threshold for unconditional advantage of single photons over laser light, and show insights on the interplay between single-photon purity and collected brightness in the performances of BB84.

Invited Talk Q 59.6 Thu 16:00 P 7

Metropolitan Quantum Key Distribution based on Room Temperature Single Photon Source — •Haoran Zhang — School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore, Singapore

Quantum Key Distribution (QKD) is a cryptographic technology that supports the negotiation and sharing of private keys with unconditional security between authorized parties. As QKD scales to a global level, it must address performance limitations, high costs, and practical security concerns. For the deployment of QKD using single-photon sources (SPSs), existing demonstrations are still limited to operation at cryogenic temperatures. We realized the first demonstration of QKD based on a telecommunication-wavelength SPS operating at room temperature, as well as the first metropolitan-scale SPS-based QKD experiment at room temperature, paving the way for the commercial deployment of SPS-based QKD systems.