MON 13: QIP Implementations: Photons II

Time: Monday 16:30–18:00 Location: ZHG001

MON 13.1 Mon 16:30 ZHG001

Distinguishability, mixedness and symmetry in multiphoton quantum interference — •Shreya Kumar[1], Alex E Jones[2], Matthias Bayerbach[1], Simone D'Aurelio[1], Nico Hauser[1], and Stefanie Barz[1] — [1]Institute for Functional Matter and Quantum Technologies, and IQST, University of Stuttgart, 70569 Stuttgart, Germany — [2]2QET Labs, University of Bristol, Bristol BS8 1FD, UK

Quantum interference is fundamental to many quantum technologies and is governed by properties such as distinguishability, mixedness, and the symmetry of quantum states. Here, we present how these properties influence multiphoton scattering statistics. In particular, we demonstrate that three photons can exhibit distinct scattering statistics depending on whether they are in pure or mixed states, even when they display identical pairwise Hong-Ou-Mandel (HOM) interference. This highlights that pairwise HOM interference is insufficient to fully characterise multi-photon quantum interference. We further investigate the role of quantum state symmetry in quantum interference. Together, these results provide new fundamental insights into the nature of quantum interference and highlight the role of distinguishability, mixedness, and symmetry in multiphoton interference. Apart from providing fundamental insight into the nature of quantum interference, our results have significant implications for quantum technologies that rely on photonic interference, including quantum computing and quantum simulation.

MON 13.2 Mon 16:45 ZHG001

Switching, Amplifying, and Chirping Diode Lasers with Current Pulses for High Bandwidth Quantum Technologies — •Gianni Buser, Roberto Mottola, Suyash Gaikwad, and Philipp Treutlein — Universität Basel, Departement Physik, Klingelbergstrasse 82, 4056 Basel, Schweiz

High-bandwidth asynchronous (fast and triggered) operation is key to establishing the technological relevance of current proof-of-principle quantum devices. Therein, achieving sufficient speed and contrast in amplitude and phase modulation of light is a widespread performance limitation. For instance, quantum memories storing photons in collective matter excitations by optical control often suffer from unintentional readout due to leaking control light during the storage time [1,2]. Moreover, the control intensities are regularly such, that two-photon process like read/write operations technically require chirped pulses to remain on resonance over the course of their dynamics because of induced atomic level shifts. This talk describes direct current modulation methods that grant independent phase and amplitude control over diode lasers. A system capable of producing watt power level, nanosecond duration optical pulses with 60 dB intensity contrast between their on and off states and simultaneous chirps at rates up to 150 MHz/ns on demand [3] is presented, and application to high bandwidth quantum technology is discussed. [1] PRX Quantum 3, 020349 (2022), [2] PRL 131, 260801 (2023), [3] RSI 95, 123001 (2024).

MON 13.3 Mon 17:00 ZHG001

Applications of boosted Bell-state measurements — Matthias J. Bayerbach[1,2], •Simone E. D'Aurelio[1,2], and Stefanie Barz[1,2] — [1]Institute for Functional Matter and Quantum Technologies, University of Stuttgart, Stuttgart, Germany. — [2]Center for Integrated Quantum Science and Technology (IQST), University of Stuttgart, Stuttgart, Germany

Bell-state measurements are a key component to realize in many quantum communication and computing applications. They are at the heart of quantum repeaters or measurement-device-independent quantum key distribution protocols and essential in the generation of larger entangled state in measurement-based quantum computing. Linear optical implementations are favourable due to their simplicity, but limited in their success rates. Boosting the success rate of these measurements with ancillary photons allow one to overcome this flaw, while keeping the advantages of linear optics.

In this talk, we present experimental implementations of such a scheme. We demonstrate boosted quantum teleportation and boosted entanglement swapping, both critical components of a quantum repeater. Using single photon sources at 1550 nm, our system is compatible with existing telecommunication infrastructure. Our work demonstrated the practicality and usefulness of ancillary state boosting for any application relying on Bell-state measurements.

MON 13.4 Mon 17:15 ZHG001

Generation a 3-mode NOON state with heralding — •Sukhjit Singh, Emanuele Polino, Farzad Ghafari, Simon White, Geoff Pryde, Sergei Slussarenko, and Nora Tischler — Queensland Quantum and Advanced Technologies Institute and Centre for Quantum Computation and Communication Technology, Griffith University, Yuggera Country, Brisbane, QLD 4111, Australia

The preparation of photonic entangled states is generally probabilistic, and their successful generation is mainly verified by destructively measuring them (post-selection), making them impractical for many large-scale applications. This problem can be avoided by heralding, which means creating the entangled state with additional photon(s) in ancilla modes, and upon only measuring these modes, the desired state's successful generation can be verified.

Multi-mode NOON states, a coherent superposition of N photons in one mode and none in the other d modes, are optimal probes for multiphase sensing and key resources for phase imaging in optical microscopy. However, it must be generated in a heralded manner. Only then can it be used efficiently to perform phase sensing, without reducing the Fisher information due to failed state generation attempts.

Using single photons, linear optics and SNSPDs, we have experimentally created for the first time a 3-mode NOON state whose successful generation can be verified by detecting one and only one auxiliary photon in an additional mode: $(|2,0,0> + |0,2,0> + |0,0,2>)|1>$.

MON 13.5 Mon 17:30 ZHG001

Homodyne detection of pulsed squeezed states of light for Gaussian Boson Sampling — •Florian Lütkewitte[1], Sanaz Haddadian[2], Mikhail Roiz[1], Kai Hong Luo[1], Jan-Lucas Eickmann[1], J. Christoph Scheytt[2], Benjamin Brecht[1], Michael Stefszky[1], and Christine Silberhorn[1] — [1]Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, 33098, Paderborn, Germany — [2]System and Circuit Technology Group, Heinz Nixdorf Institute, Paderborn University, 33102 Paderborn, Germany

With the advent of complex, hybrid photonic networks such as Gaussian Boson Sampling (GBS), it becomes increasingly important to produce high-quality single-spectral-mode single-mode squeezed states of light (SMSS), requiring precise engineering of spectral properties. Here, SMSS are generated by interfering the modes of a decorrelated, spectrally indistinguishable two-mode squeezed state.

Naturally, one also needs to verify the quality of these states, which can be done using single-shot homodyne detection, requiring tailored electronics and optics. This detection scheme also enables time-multiplexed architectures and measurement of complex heralded quantum states by post-selection. Here, we will show the suitability of single-shot homodyne detection for characterizing single-spectral-mode single-mode squeezed states for GBS

MON 13.6 Mon 17:45 ZHG001

Demonstration of free-electron-photon entanglement — •Jan-Wilke Henke[1,2], Hao Jeng[1,2], Murat Sivis[1,2], and Claus Ropers[1,2] — [1]Max Planck Institute for Multidisciplinary Sciences, Göttingen, Germany — [2]University of Göttingen, 4th Physical Institute, Göttingen, Germany

Most emerging quantum technologies including quantum computation and sensing rely on quantum entanglement. Verifying the entanglement between different quantum system is thus of high relevance. While the interaction of free electrons with optical fields is expected to induce free electron-photon entanglement [1,2], its proof has been an outstanding challenge.

Here, we demonstrate quantum entanglement between free electrons and photons [3]. Harnessing a quantum eraser-type setup [4], we employ dual electron beams in a transmission electron microscope that generate photons of distinct polarisation at a nanostructure. The joint electron-photon state is reconstructed from measurements in different bases and shown to violate the Peres-Horodecki entanglement criterion by more than 7 standard deviations. This proof of electron-photon entanglement will be a cornerstone of free electron quantum optics, enabling quantum-enhanced sensing in electron microscopy.

[1] O. Kfir, Phys. Rev. Lett. 123, 103602 (2019);
[2] A. Konecńa, F. Iyikanat, and F. J. García de Abajo, Sci. Adv. 8, eabo7853 (2022);
[3] J.-W. Henke et al., arXiv:2504.13047 (2025);
[4] J.-W. Henke, H. Jeng & C. Ropers, Phys. Rev. A 111, 012610 (2025)