Q 40: Quantum Optics and Nuclear Quantum Optics II

Time: Wednesday 14:30–16:30 Location: AP-HS

Q 40.1 Wed 14:30 AP-HS

From click counts to photon numbers — •Suchitra Krishnaswamy, Fabian Schlue, Laura Ares, Vladymir Dyachuk, Michael Stefszky, Benjamin Brecht, Christine Silberhorn, and Jan Sperling — Paderborn University, Institute for Photonic Quantum Systems (PhoQS), Warburger Straße 100, 33098 Paderborn, Germany

Photon-number measurements are a cornerstone in quantum photonics, making photon-number-resolving detectors an essential tool. Because of wider accessibility, imperfect detectors, one of them being click detectors, are often used. Click detectors register a click irrespective of the number of incoming photons, and no click otherwise, thus displaying statistical properties different from common detection models. Utilizing click counting theory, photon statistics were reconstructed via an analytic pseudo-inversion method. Theoretically, this approach can be extended to higher click-number-resolving detectors. A reconfigurable time-bin multiplexing, click-counting detector is experimentally implemented. We gauge the success of the pseudo-inversion by applying the Mandel and binomial parameters that help in distinguishing quantum statistics.In the case of coherent light (classical-nonclassical boundary), both parameters are highly sensitive measures, hence a perfect way to gauge the reconstruction performance. Additionally, we apply a deconvolution technique to account for detection losses.

Q 40.2 Wed 14:45 AP-HS

Interference effects in an electron-driven quantum emitter — •Hebrew Crispin[1] and Nahid Talebi[2] — [1]Christian-Albrechts-Universität, Kiel, Germany — [2]Christian-Albrechts-Universität, Kiel, Germany

Cathodoluminescence spectroscopy has emerged as a platform for studying the quantum aspects of light on the nanoscale. Since the experimental demonstration of photon anti-bunching and super-bunching effects by electron excitations, considerable efforts have been devoted towards understanding the electron-matter interactions and the light emission in cathodoluminescence. A theoretical description of the observed photon statistics has been provided by several authors. However, the majority of these approaches rely on classical models. In addition, the electron-beam-excitations of only two-level systems has been the focus so far. Here, we propose a theoretical framework for cathodoluminescence from a multi-level quantum emitter. Modeling the electron-beam-excitation as an incoherent broadband field driving the emitter, we obtain a quantum optical master equation for the system. We show that the presence of different transition pathways can give rise to quantum interference effects. The induced interference significantly modifies the emitter dynamics and the time-dependent spectra. We find that the interference is sensitive to the excitation rate, the initial coherence, and the excited level splitting. Our model reveals the possibility of electron-beam-induced quantum interferences in cathodoluminescence emission and provides a framework to explore quantum optical effects in electron-driven multi-level systems.

Q 40.3 Wed 15:00 AP-HS

Evaluating the quality of heralded photon-number states with high-order moments — •Daniel Borrero Landazabal and Kaisa Laiho — German Aerospace Center (DLR), Institute of Quantum Technologies, Wilhelm-Runge-Str. 10, 89081 Ulm, Germany

Typically, the fidelity and second-order correlation function $g(2)$ are used to characterize number states. While the fidelity gives insights on the purity, a low $g(2)$-value indicates a low multiphoton contributions of the target state. However, the fidelity is not straightforward to measure in an experimental setup, and $g(2)$ ignores the vacuum component, which degrades the state quality. In this work, we propose and numerically demonstrate that the photon-number parity represents a practical and improved tool in state characterization, when accessed via the higher-order factorial moments of photon number [1]. By taking into account imperfections of photon counting systems [2], we successfully simulate the characteristics of heralded number states up to three photons from a twin beams generated in a non-linear optical process of parametric down-conversion. Furthermore, we express our results in an easy experimentally accessible parameter space, which allows identifying optimal regions for the number-state generation with high-quality.

[1] K. Laiho et al., "Measuring higher-order photon correlations of faint quantum light: a short review", Phys. Lett. A 435, 128059 (2022).

[2] J. Sperling et al., "True photocounting statistics of multiple on-off detectors", Phys. Rev. A 85, 023820 (2012).

Q 40.4 Wed 15:15 AP-HS

Distance of pure two-mode Gaussian states and the validity of the rotating wave approximation — •Tim Heib — Theoretical Physics, Universität des Saarlandes, 66123 Saarbrücken, Germany — Institute for Quantum Computing Analytics (PGI-12), Forschungszentrum Jülich, 52425 Jülich, Germany

We quantify the deviation of arbitrary pure two-mode Gaussian states that evolve through different dynamics from a common quantum state, where the dynamics are induced by quadratic Hamiltonians. We show that this distance is fully determined by the first and second moments of the statistical distribution of the number of excitations created from the vacuum during an appropriate effective time evolution.

We employ these results exemplary for the rotating wave approximation and provide proof for its viability under suitable initial conditions.

Q 40.5 Wed 15:30 AP-HS

Heralded squeezed coherent state superpositions via optical catalysis — •Roger Kögler[1], Elnaz Bazzazi[1], Ananga Datta[1], Julian Nauth[2], Nathan Walk[2], Marco Schmidt[1], and Oliver Benson[1] — [1]Humboldt-Universität zu Berlin, Institut für Physik, Newtonstraße 15, 12489, Berlin, Germany — [2]Dahlem Center for Complex Quantum Systems, Freie Universität Berlin, Arnimallee 14, 14195 Berlin, Germany

Non-Gaussian states of light are strong candidates for fault tolerant-encoding and error correction in future quantum computation implementations. Their experimental generation, however, remains challenging and relies in different quantum state engineering techniques. In this work, we investigate a photon catalysis-like protocol and its suitability for generating high-amplitude squeezed coherent state superpositions (SCSS) in optical platforms. The method involves the interference of squeezed and Fock states at a beamsplitter, followed by a photon number resolving (PNR) detection in one of the output modes. The remaining mode is thereby projected into a state determined by the resource states, the beamsplitter splitting ration, and the PNR outcome. Analytical results are used to evaluate different output states and their overlap with target SCSS states. The impact of losses on the protocol is studied using numerical simulations, with results visualized in phase-space representations. This study is conducted in parallel with its experimental implementation, aiming toward the optical tomography of catalyzed states.

Q 40.6 Wed 15:45 AP-HS

Characterization of multimode linear optical devices using single photon and two-photon correlation measurements — •Cheeranjiv Pandey, Kai Hong Luo, Simone Atzeni, Fabian Schlue, Florian Lütkewitte, Jan-Lucas Eickmann, Mikhail Roiz, Michael Stefszky, Benjamin Brecht, and Christine Silberhorn — Paderborn University, Integrated Quantum Optics, Institute for Photonic Quantum Systems (PhoQS), Warburger Str. 100, D-33098, Germany

Photonics has emerged as a promising platform for implementing various quantum computational and communication schemes. At the heart of many such schemes lie multimode linear optical devices, composed of integrated arrays of beam splitters and phase shifters. Previous works have demonstrated that any arbitrary unitary matrix can be decomposed into an array of beam splitters and phase shifters. Consequently, these devices can implement any unitary transformation between input and output channels by precisely controlling the beam splitters' transmittivities and the phase shifts introduced by the phase shifters. However, such devices often deviate from their ideal behavior due to fabrication imperfections and thermal cross-talk between components. As a result, precise characterization of these devices is critical to ensure their effective functionality in various applications. We showcase our ongoing research focused on developing characterization techniques that will allow us to reconstruct the transformation matrix of a multimode linear optical device by means of single-photon and two-photon correlation measurements.

Q 40.7 Wed 16:00 AP-HS

Enhancement in stimulated Raman with squeezed states of light — •Shahram Panahiyan[1,2], Frank Schlawin[1,2,3], and Dieter Jaksch[1,2,3] — [1]University of Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [2]Max Planck Institute for the Structure and Dynamics of Matter, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]The Hamburg Centre for Ultrafast Imaging, Luruper Chaussee 149, Hamburg D-22761, Germany

The stimulated Raman process (SRP) is a critical technique in microscopy and spectroscopy, enabling applications such as real-time imaging of living cells and organisms [1,2]. Given the significance of SRP for photosensitive materials, there is considerable interest in enhancing its resolution without relying on high-intensity laser fields. To address this challenge, we leverage squeezed states of light, which exhibit reduced quantum fluctuations and improved signal-to-noise ratios, to investigate SRP. Our study highlights the benefits of utilizing squeezed light to enhance the precision of SRP measurements and compares its performance to that of classical light fields. [1] R. B. de Andrade et al., Optica 7, 470 (2020). [2] C. A. Casacio et al., Nature 594, 201 (2021)

Q 40.8 Wed 16:15 AP-HS

Relation between optical quantum computers and quantum computers — •Jannes Ruder[1] and Hans-Otto Carmesin[1,2,3] — [1]Gymnasium Athenaeum, Harsefelder Straße 40, 21680 Stade — [2]Studienseminar Stade, Bahnhofstr. 5, 21682 Stade — [3]Universität Bremen, Fachbereich 1, Postfach 330440, 28334 Bremen

Quantum computers use linear superposition and entanglement, in order to solve appropriate problems much faster than electronic computers. Some optical quantum computers use the qubits the orbital angular momentum and polarization, as well as the universal set of quantum gates consisting of the Hadamard gate, the CNOT - gate and the $\frac{\pi}{4}$ - gate.

While the light sources of quantum computers are single photon sources, the light sources of optical computers are lasers. Accordingly, optical computers can be built in a more straight forward, cheap and elegant manner than optical quantum computers. So the question arises, whether optical computers can solve tasks at a rapidity similar to that of optical quantum computers.

For it, we show theoretically and experimentally that optical computers can use the same above mentioned qubits and the same universal set of quantum gates as optical quantum computers.