Q 35: Quantum States of Light

Time: Wednesday 14:30–16:30 Location: HS 3118

Invited Talk Q 35.1 Wed 14:30 HS 3118

Quantum correlations in the phase space — Martin Bohmann[1], Jan Sperling[2], Nicola Biagi[3,5], Alessandro Zavatta[3,4], Marco Bellini[3,5], and •Elizabeth Agudelo[6] — [1]Quantum Technology Laboratories GmbH, 1100 Vienna, Austria — [2]PhoQS, Paderborn University, 33098 Paderborn, Germany — [3]CNR-INO, 50125 Florence, Italy — [4]QTI S.r.l., 50125 Florence, Italy — [5]LENS and Department of Physics and Astronomy, University of Firenze, 50019 Florence, Italy — [6]TU Wien, Atominstitut, 1020 Vienna, Austria

Today, we are utilizing quantum physics to propel advancements in quantum information science and technology, yet there remain unanswered fundamental inquiries about the nature of quantum and its ability to exceed classical boundaries. Our strategy includes characterizing physical systems within phase space. In my presentation, I will examine the boundary between quantum and classical realms, introducing innovative, mathematically robust techniques for practical applications. These methods offer distinct insights into what differentiates the classical world from the quantum domain, and also facilitate the characterization of quantum states of light. For instance, we will confirm effects that surpass classical correlations using a theory that is friendly to experimental settings. We will showcase cutting-edge techniques for differentiating between classical and quantum phenomena that coexist in quantum optics experiments. This involves introducing concepts like nonclassicality quasiprobabilities and phase space inequalities, and investigating quantum effects in correlated systems, including hybrid systems.

Q 35.2 Wed 15:00 HS 3118

Quantum and Classical Information Flow in Phase Space — •Moritz F. Richter and Heinz-Peter Breuer — Institute of Physics, University of Freiburg, Germany

Exchange of information between an open quantum system and its environment, especially the backflow of information to the system associated with quantum notions of non-Markovianity, is a widely discussed topic for years now [1]. Usually the information flow is quantified by the increase of suitable distance measures between two initial states of the open quantum system at hand. However, the same idea can also be used to identify information backflow in classical systems and their dynamics in phase space. In the talk we will address how information backflow of a continuous variable (CV) quantum system can be quantified by means of its phase space representation - i.e. quasi-probability distributions - and how this leads to a notion of non-Markovianity using distance measures between probability distributions representing classical states in phase space [2]. [1] Breuer H-P, Laine E-M, Piilo J and Vacchini B; 2016 "Colloquium: non-Markovian dynamics in open quantum systems"; Rev. Mod. Phys. 88 021002

[2] Richter M F, Wiedemann R and Breuer H-P; 2022 "Witnessing non-Markovianity by quantum quasi- probability distributions"; New J. Phys. 24 123022

Q 35.3 Wed 15:15 HS 3118

Towards Large Schrödinger Cat States with Optical Photons — •Hendrik Hegels, Michael Eichenberger, Stephan Dürr, and Gerhard Rempe — Max Planck Institute of Quantum Optics, Hans-Kopfermann-Str. 1, 85748 Garching, Germany

Large Schrödinger cat states allow probing the border between quantum physics and classical physics. At the same time, they provide a valuable resource for continuous variable quantum computing, quantum communication and quantum error correction schemes. In practice these applications require Schrödinger cat states with mean photon number $\gtrsim 4$. There are several experimental demonstrations of optical cat states, but so far none could reach or even surpass this limit. Here, we present an apparatus based on Rydberg-EIT in an atomic ensemble in an optical cavity that has the potential to overcome this limit and produce large optical cat states for the first time.

Q 35.4 Wed 15:30 HS 3118

Tailoring the sensitivity of gravitational-wave detectors to neutron star merger signals with internal squeezing — •Niels Böttner, Mikhail Korobko, Joe Bentley, and Roman Schnabel — Institut für Quantenphysik und Zentrum für Optische Quantentechnologien der Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany

The observation of gravitational waves from binary neutron star mergers is an excellent opportunity to study them and their fundamental properties. During the late inspiral, gravitational waves in the kilohertz-band are generated that contain information about nuclear matter at extreme densities. However, current gravitational-wave observatories are not sensitive enough to detect these gravitational waves because they are limited by quantum noise. Here, we propose to flexibly tune the sensitivity in the kilohertz-band with a new concept called Twin Recycling Quantum Expander. The design of this concept corresponds to a dual-recycled Fabry-Pèrot-Michelson interferometer that we customized by adding a second recycling cavity to it and by placing a nonlinear crystal inside the signal recycling cavity to generate squeezed states of light. The coupled cavity structure and the generated squeezing improve the signal-to-noise ratio at high frequencies. We demonstrate that our new concept allows us to increase and tune the sensitivity in the kilohertz-band, bringing the additional level of flexibility and enhancement to the existing concepts of future detectors. We anticipate our results to be a valuable new approach for the design of future gravitational wave detectors.

Q 35.5 Wed 15:45 HS 3118

Photon Bose–Einstein Condensate in a Planar Cavity in the Thermodynamic Limit — •Andris Erglis[1] and Stefan Yoshi Buhmann[2] — [1]University of Freiburg, Freiburg, Germany — [2]University of Kassel, Kassel, Germany

It has been of general interest to explore the different behaviour of a Bose–Einstein condensate (BEC) for finite versus infinite systems. For instance, the critical number of particles in two dimensions diverges in the thermodynamic limit, while being well-defined for a system of finite size.

We are investigating the photon BEC inside a two dimensional planar cavity at the crossover between finite and infinite size, where our control parameter is the transversal mode spacing. In addition to the usual primary condensation threshold, we observe arrested condensation and an emergence of a second critical threshold proportional to the mode spacing, where the condensate is forming. This result, which we have derived using an analytical two-mode solutions, is corroborated by numerical simulations for larger mode numbers.

Q 35.6 Wed 16:00 HS 3118

Creation of Non-Gaussian Quantum States with a GBS-like device — •Gil Zimmermann[1,2], Marius Leyendecker[1,2], René Sondenheimer[1,2], and Fabian Steinlechner[1,2] — [1]Friedrich Schiller University, Jena, Germany — [2]Fraunhofer IOF, Jena, Germany

Non-Gaussian quantum states play an important role in quantum information, quantum computing and quantum sensing. There are many different protocols to generate different non-Gaussian states. One system, which is a generalisation of many of these protocols, is based on a so-called Gaussian boson sampling (GBS) type device. The advantage of this is that different non-Gaussian states can be produced with just one system. The GBS-like device consists of an N-mode linear interferometer that can implement any unitary transformation. N single mode Gaussian quantum states are injected into the interferometer and N-M modes are measured in the output with the aid of photon number resolving (PNR) detectors. A resulting quantum state is present in the remaining M output modes of the interferometer. By varying the propterties of the input states and the linear interferometer and considering different outcomes at the PNR detectors, optimisation algorithms can be designed regarding fidelity and generation probability. This allows us to find parameters for the best possible circuit that generates a specific M-mode non-Gaussian output state. In this work, a parameter study regarding the GBS-like device is carried out. For various single and multimode non-Gaussian states, we analyse the experimental feasibility under the presence of loss.

Q 35.7 Wed 16:15 HS 3118

Gaussian state generation with Gaussian-Boson-Sampling like setups — •Marius Leyendecker[1,2], Gil Zimmermann[1,2], René Sondenheimer[1,2], and Fabian Steinlechner[1,2] — [1]Friedrich Schiller University, Institute for Applied Physics, Abbe Center of Photonics, Jena, Germany — [2]Fraunhofer Institute for Applied Optics and Precision Engineering IOF , Jena, Germany

Non-Gaussian states have numerous applications in quantum computation, quantum metrology, and quantum communication. It has been shown that Gaussian Boson Sampling (GBS) devices in combination with detection post-selection can be used to generate many optical non-Gaussian states. This is implemented by interfering N input squeezed states on an N-mode linear interferometer. We study an optimization algorithm for an M-mode target state depending on the properties of the input states and the interferometer. These states are heralded by N-M photon-number resolving measurements on the other output states. As losses have a substantial influence on the fidelity of the produced output state, simple interferometer architectures comprising of only few optical elements, e.g. in a time-bin loop architecture with one loop, will be analyzed. While in [1] a variety of entangled Gaussian states have been demonstrated in a time-bin loop architecture and [2] explores the capability of the architecture for GKP states, we will explore the capabilities of the time-bin architecture for non-gaussian states with lower demands on experimental resources.

[1] Shuntaro Takeda et al. , DOI:10.1126/sciadv.aaw4530
[2] Takase, K., et al. DOI: 10.1038/s41534-023-00772-y