Q 26: Quantum Optics IV

Time: Tuesday 14:30–16:00 Location: f442

Q 26.1 Tue 14:30 f442

Quadrature squeezed photons from a two-level system — Carsten Schulte, Jack Hansom, Alex Jones, •Clemens Matthiesen, Claire Le Gall, and Mete Atature — Cavendish Laboratory, University of Cambridge, United Kingdom

The interaction of a two-level atom with a resonant light field is of fundamental importance in quantum optics. Despite its conceptual simplicity it gives rise to intriguing phenomena, such as the Mollow triplet, antibunching and coherent light scattering.

While quantum optics experiments have traditionally been confined to the realms of atomic optics, the past 15 years have seen a branching out from 'natural' to 'artificial atoms' such as semiconductor quantum dots.

Enabled by the high scattering rate of a resonantly driven self-assembled InGaAs quantum dot we verify a prediction from the 1980s that the quantum fluctuations in the stream of single photons are below the fundamental level set by the vacuum fluctuations [1]. We employ homodyne intensity correlations to observe quadrature squeezing in single-atom resonance fluorescence for the first time [2].

[1] D.F. Walls and P. Zoller, PRL 47, 709 (1981).
[2] C. H. H. Schulte et al., Nature 525, 222 (2015).

Q 26.2 Tue 14:45 f442

Squeezed Light from Entangled Nonidentical Emitters via Nanostructured Environments — Harald R. Haakh and •Diego Martin-Cano — Nano-Optics Division, Max Planck Institute for the Science of Light, Erlangen, Germany.

Most sources of squeezed light are based on large systems, such as nonlinear crystals or atomic vapors. Recent experiments [1,2] have proven quadrature squeezing in scattered resonance fluorescence from a single emitter, a long-standing prediction in quantum optics [3]. To assist the weak signals in such challenging measurements and to push the limits of their generation, we have recently researched the ability of nanostructures to create squeezed light from a single two-level emitter [4]. Here we present a step forward by studying nonclassical properties in collective resonance fluorescence aided by nanostructures [5]. The broadband character of the nano-architecture allows for an enhanced two-photon nonlinearity that generates squeezed light from two far-detuned quantum emitters. Our approach permits to overcome the intrinsic limitations from noninteracting single emitters and is more robust against phase decoherence induced by the environment. More generally, we show that the reduced light fluctuations arising from the interaction between the emitters provide a means to detect their entanglement. **References:** [1] C. Schulte et al., Nature **525**, 222 (2015). [2] A. Ourjoumtsev et al, Nature **474**, 623 (2011) [3] D. Walls and P. Zoller, PRL **47**, 709 (1981). [4] D. Martin-Cano et al, PRL **113**, 263605 (2014). [5] H. Haakh and D. Martin-Cano, ACS Phot, DOI:10.1021/acsphotonics.5b00585.

Q 26.3 Tue 15:00 f442

Optical Harmonic Generation from Bright Squeezed Vacuum — •Kirill Spasibko[1,2,3], Denis Kopylov[3], Tatiana Murzina[3], Maria Chekhova[1,2,3], and Gerd Leuchs[1,2] — [1]MPI for the Science of Light, Erlangen, Germany — [2]FAU Erlangen-Nürnberg, Erlangen, Germany — [3]M.V.Lomonosov MSU, Moscow, Russia

Bright squeezed vacuum (BSV) is a macroscopic but still highly nonclassical state of light. Its non-classical features include quadrature and two-mode squeezing. Moreover with this state even the Bell inequalities could be, in principle, violated. Due to the high brightness, BSV is very attractive for any nonlinear light-matter interactions, where it provides much higher efficiency than faint non-classical states of light.

The simplest case is the generation of optical harmonics. Usually it is done with laser beams that have coherent statistics. Depending on the conditions, single-mode BSV has thermal or superbunched statistics. Such statistics leads to the enhancement in the generation of the m-th harmonic by a factor of m! or (2m-1)!! compared to coherent light with the same mean intensity. For example, for the generation of the second (third) harmonics the enhancement factors are 2 (6) and 3 (15). Thus, BSV offers higher sensitivity in nonlinear interactions with the same mean intensity, which is important for fragile samples.

Here we study the generation of the second and third harmonics from the filtered single-mode and multimode BSV radiation. We compare harmonics generation from single-mode superbunched BSV, single-mode BSV with thermal statistics, and multimode BSV mimicking coherent radiation.

Q 26.4 Tue 15:15 f442

An Operational Measure for Squeezing — •Martin Idel, Daniel Lercher, and Michael M. Wolf — Technische Universität München, Zentrum Mathematik, M5, Garching, Deutschland

Squeezing of quantum states in continuous variable systems is valuable albeit difficult since it always requires the use of nonlinear media. From a mathematical perspective, this makes it an interesting resource theory. We introduce two operational measures for squeezing for multimode quantum systems: the first measure quantifies the integrated interaction strength of active Hamiltonians required to prepare the given state. The second measure may be dubbed "squeezing of formation" as it is the squeezing analogue of the well-known entanglement of formation. The two measures are shown to be equivalent and we prove some of their properties such as convexity and continuity. Moreover, we derive simple bounds and provide a convex programming algorithm for computing the measure. Finally, we show an example where the preparation procedures obtained from the measure are superior (in terms of squeezing needed) to naive preparation procedures.

Q 26.5 Tue 15:30 f442

Quantumness Quantification — •Melanie Mraz[1], Jan Sperling[2], Werner Vogel[2], and Boris Hage[1] — [1]AG Experimentelle Quantenoptik, Insitut für Physik, Universität Rostock, Rostock, Deutschland — [2]AG Theoretische Quantenoptik, Insitut für Physik, Universität Rostock, Rostock, Deutschland

Nonclassical quantum states have an advantage over classical states for various applications. Hence, it is of a fundamental interest to study properties of these states. It is already possible to say if a state is nonclassical or not, but how can we decide how much nonclassicality is in our system? We propose a degree of nonclassicality being a nonclassicality measure. It is determined by the decomposition of a quantum state into superpositions of coherent states. On the one hand, coherent states resembles the behavior of a classical harmonic oscillator most closely. On the other hand, the more quantum superpositions of coherent states are needed, the more quantum interferences arise. A method for such a decomposition of quantum states is presented and the degree of nonclassicality is determined for different states theoretically. Following this approach the next step is to apply this measure to an experiment. But how can we extract the information necessary to estimate the amount of quantumness in our system? Therefore pattern functions are used to reconstruct a density matrix in coherent state basis. This basis is chosen as the quantumness measure itself is based on superpositions of coherent states. Using this method we will try to witness the amount of nonclassicality in our system.

Q 26.6 Tue 15:45 f442

Unified nonclassicality criteria and continuous sampling — •Semjon Köhnke, Sergej Ryl, Elizabeth Agudelo, Jan Sperling, Melanie Mraz, Boris Hage, and Werner Vogel — Arbeitsgruppe Experimentelle Quantenoptik, Institut für Physik, Universität Rostock, D-18059 Rostock, Germany

One principle scope of quantum physics is the formulation of measurable conditions, which are fulfilled for classical systems but may be violated for nonclassical ones. Hence a number of nonclassicality criteria have been formulated to certify quantum features of states.

One hierarchy is based on Bochner's theorem and the characteristic function of the Glauber-Sudarshan representation (P function). Another hierarchy is formulated in terms of the matrix of moments. We combine the advantages of the CF and the MOM of the P function, resulting in a generalization of Bochner's theorem. For applications of the generalized nonclassicality probes, we provide direct sampling formulas for balanced homodyne detection. A squeezed vacuum state is experimentally realized and characterized with our method.

Furthermore we present a continuous phase sampling technique. In contrast to discrete phase-locked measurements, the continuous sampling of a regularized P function allows an unconditional verification of nonclassicality, as we demonstrate for the phase-sensitive squeezed vacuum state.