Q 11: Quantum Optics I

Time: Monday 14:00–16:00 Location: f342

Q 11.1 Mon 14:00 f342

Super-resolution imaging of a single atom: the role of orbital angular momentum — •Martin Drechsler[1,2], Sebastian Wolf[1], Elias Alstead[1], Ferdinand Schmidt-Kaler[1], and Christian Schmiegelow[2] — [1]QUANTUM, Institut für Physik, Johannes Gutenberg-Universität Mainz — [2]Departamento de Física, FCEyN, UBA and IFIBA, UBA CONICET

Cold trapped ions are one of the most precise platforms to probe light matter interaction, due to the high level of control and isolation from the environment. Recently, it was shown that by using beams with orbital angular momentum, quadrupole transitions of a single $^{40}Ca^{+}$ ion can be excited when placing the ion in places where the light intensity vanishes [1, 2]. In this work, we present a method to take advantage of this effect to perform an analogous of Stimulated Emission Depletion Microscopy (STED) [3] to image the wave function of a single trapped ion.

[1] Schmiegelow, C. T., Schulz, J., Kaufmann, H., Ruster, T., Poschinger, U. G., Schmidt-Kaler, F. (2016). *Transfer of optical orbital angular momentum to a bound electron.* Nature communications, 7, 12998.

[2] Quinteiro, G. F., Schmidt-Kaler, F., Schmiegelow, C. T. (2017). *Twisted-light ion interaction: the role of longitudinal fields.* Phys. Rev. Lett., 119(25), 253203.

[3] Hell, S. W. (2003). *Toward fluorescence nanoscopy.* Nature biotechnology, 21(11), 1347.

Q 11.2 Mon 14:15 f342

Spectral properties of single photons from a single ^{40}Ca^{+} ion — Matthias Kreis, •Omar Elshehy, and Jürgen Eschner — Universität des Saarlandes, Experimentalphysik, 66123 Saarbrücken

Single photons with well-controlled spectral and temporal properties are an essential resource for optical quantum communication protocols such as quantum repeaters.

We investigate single photons at 393 nm wavelength generated from a single $^{40}Ca^{+}$-ion by a controlled Raman scattering process in the Λ-shaped 3-level configuration consisting of the $D_{5/2}(m = -5/2)$, $P_{3/2}(m=-3/2)$, and $S_{1/2}(m=-1/2)$ Zeeman levels.

The spectral properties of the Raman photons are analyzed by a 396 mm long scanning Fabry-Perot cavity with 1 MHz transmission bandwidth stabilized to a 393 nm reference laser. Spectra are taken for various values of Rabi frequencyy and detuning of the 854 nm driving laser, and compared to calculated spectra, following the theory in [1].

[1] P. Müller et al., Phys. Rev. A **96**, 023861 (2017).

Q 11.3 Mon 14:30 f342

Coherent and incoherent many-particle interference tests of Born's rule — •Marc-Oliver Pleinert[1,2], Eric Lutz[3], and Joachim von Zanthier[1,2] — [1]Institut für Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91058 Erlangen, Germany — [2]Erlangen Graduate School in Advanced Optical Technologies (SAOT), Friedrich-Alexander-Universität Erlangen-Nürnberg (FAU), 91052 Erlangen, Germany — [3]Institute for Theoretical Physics I, University of Stuttgart, D-70550 Stuttgart, Germany

Quantum mechanics is based on a set of only a few postulates, which can be separated into two parts: one part governing the 'inner' structure, i.e., the definition and dynamics of the state space, the wave function and the observables; and one part making the connection to experiments ('external' world). Here, we focus on the second part, in particular Born's rule, which - simply put - relates detection probabilities to the modulus square of the wave function. Born's rule can be tested in interference experiments, where the configuration of possible paths can be precisely controlled and compared. In such experiments, according to Born's rule, M-particle correlations of mutually coherent sources (MCS) are limited to order 2M, while M-particle correlations of mutually incoherent sources (MIS) are limited to order M. Excluding any higher-order correlations is hence a direct test of Born's rule and thus quantum mechanics itself. We demonstrate the vanishing of such higher-order terms in two-particle experiments for MCS and in two-, three-, and four-particle experiments for MIS.

Q 11.4 Mon 14:45 f342

Spatial entanglement and state engineering via four-photon Hong-Ou-Mandel interference — •Alessandro Ferreri, Vahid Ansari, Christine Silberhorn, and Polina Sharapova — University of Paderborn, Paderborn, Germany

Entangled photon states are fundamental element of quantum information and quantum communication processes. For the current state-of-the-art of optical -based technologies, the investigation of highly entangled systems, characterized by a large number of photons, is extremely important.

In this work we have investigated and maximized the degree of spatial entanglement in a spatially bipartite optical system characterized by four photons based on Hong-Ou-Mandel interference with four photons. The four photons are created by a single type-II parametric down-conversion source. With the use of such device and a proper choice of parameters, we have observed an antibunching behaviour as well as fast structured oscillations with a period of the pump wavelength in the coincidence probability. These features of the coincidence probability indicate spatial entanglement. We can modify the structure of such oscillations by varying the mode structure. Furthermore, by opportunely varying the parameters of our device, we can generate different combination of the four-dimensional Bell states. Finally, a small modification of our device allows to generate fringe pattern with smaller periodicity than the pump wavelength, that can be used to increase the sensitivity of measurement.

Q 11.5 Mon 15:00 f342

Witnessing non-classicality through large deviations in quantum optics — •Dario Cilluffo[1,2,3,4], Giuseppe Buonaiuto[3,4,5], Salvatore Lorenzo[1], Gioacchino Massimo Palma[1,2], Francesco Ciccarello[1,2], Federico Carollo[3,4], and Igor Lesanovsky[3,4,5] — [1]Università degli Studi di Palermo, Dipartimento di Fisica e Chimica - Emilio Segrè, via Archirafi 36, I-90123 Palermo, Italy — [2]NEST, Istituto Nanoscienze-CNR, Piazza S. Silvestro 12, 56127 Pisa, Italy — [3]School of Physics and Astronomy, University of Nottingham, Nottingham, NG7 2RD, United Kingdom — [4]Centre for the Mathematics and Theoretical Physics of Quantum Non-equilibrium Systems, University of Nottingham, Nottingham, NG7 2RD, United Kingdom — [5]Institut fuer Theoretische Physik, Universitaet Tuebingen, Auf der Morgenstelle 14, 72076 Tuebingen, Germany

Non-classical correlations in quantum optics as resources for quantum computation are important in the quest for highly-specialized quantum devices. The standard way to investigate such effects relies on either the characterization of the inherent features of sources and circuits or the study of the output radiation of a given optical setup. In this work we provide a natural link between the two frameworks by exploiting the thermodynamics of quantum trajectories. This procedure enables investigation of the quantum properties of the photon fields from a generic source via the analysis of the fluctuations and correlations of time-integrated quantities associated with the photon counting of the emitted light.

Q 11.6 Mon 15:15 f342

Using a genuine local oscillator for direct sampling of the Wigner function — •Johannes Tiedau[1], Christof Eigner[1], Victor Quiring[1], Laura Padberg[1], Raimund Ricken[1], Benjamin Brecht[1], Tim J. Bartley[2], and Christine Silberhorn[1] — [1]Universität Paderborn, Integrierte Quantenoptik, Warburger Str. 100, D-33098 Paderborn — [2]Universität Paderborn, Mesoskopische Quantenoptik, Warburger Str. 100, D-33098 Paderborn

Local oscillators are essential for quantum state characterisation and many encoding schemes in long-distance communication since they offer mode-selective and phase-sensitive measurements. Despite their name, typical experimental implementations of "local" oscillators in homodyne detection are directly derived from the laser source which generates the states, thereby opening security loopholes in quantum communication and information processing protocols. Here, we demonstrate an approach based on a genuinely local oscillator, which is generated at the receiver and hence does not suffer from this loophole. In order to show full control over our local oscillator we investigate a phase-sensitive two-mode squeezed vacuum state. Instead of standard strong field homodyning, we directly sample the Wigner function by phase-resolved photon counting. We show that this method is, in the strong squeezing regime, robust to a larger phase-jitter than standard homodyne detection.

Q 11.7 Mon 15:30 f342

Spectral properties of the cavity-enhanced spontaneous parametric down-conversion below the cavity threshold — •Golnoush Shafiee[1,2], Dmitry V. Strekalov[1], Alexander Otterpohl[1,2,3], Florian Sedlmeir[1], Gerhard Schunk[1], Ulrich Vogl[1], Harald G.L. Schwefel[4], Gerd Leuchs[1,2], and Christoph Marquardt[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Institute of Optics, Information and Photonics, Friedrich-Alexander University Erlangen-Nuremberg, Germany — [3]Erlangen Graduate School in Advanced Optical Technologies, Friedrich-Alexander University Erlangen-Nuremberg, Germany — [4]The Dodd-Walls Centre for Photonic and Quantum Technologies, Dunedin, New Zealand

Single photons and photon pairs are an important resource for quantum information processing. This motivated a thorough study of the spectral and temporal properties of parametric light, both above and below the Optical Parametric Oscillator (OPO) threshold. The pursuit of a higher two-photon emission rate leads into an intermediate regime where the OPO still operates below the threshold but the nonlinear cavity phenomena cannot be neglected anymore. Here, we investigate the properties of the down-converted photons from a whispering gallery resonator, using correlation measurements, from far below the threshold to close enough to the OPO threshold such that stimulated processes already become important

Q 11.8 Mon 15:45 f342

Signatures of photon-photon scattering in Hermite-Gaussian beams — •Ricardo R.Q.P.T. Oude Weernink[1,2] and Felix Karbstein[1,2] — [1]Helmholtz-Institut Jena, 07743 Jena, Germany — [2]Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, 07743 Jena, Germany

Quantum electrodynamics predicts effective nonlinear interactions between electromagnetic fields mediated by quantum vacuum fluctuations, a prominent example being photon-photon scattering. Measuring this process directly in an experiment is a difficult endeavour and has yet to be achieved. One of the toughest challenges for any experimental approach is to find scenarios allowing for a clear signal-to-background separation.

In this talk we present the following set-up: We focus on the geometrically simple scenario of two counter-propagating high-intensity laser beams, though allow them to be prepared in arbitrary Hermite-Gaussian modes or superpositions thereof. We are mainly interested in ways to enhance the discernible signal, but also study the behaviour of the signal photon number for non-optimal collisions with finite impact parameter.