Q 30: Quantum Effects: QED II / Interference and Correlations III

Time: Wednesday 14:00–16:00 Location: A 320

Q 30.1 We 14:00 A 320

On the Quantum Theory of the FEL — •Paul Preiss[1], Roland Sauerbrey[2], and Wolfgang P. Schleich[1] — [1]Institut für Quantenphysik, Universität Ulm, D-89069 Ulm, Germany — [2]Forschungszentrum Dresden-Rossendorf, D-01328 Dresden, Germany

The free-electron laser (FEL) is an alternative laser device with a widely tunable wavelength of the emitted radiation. Usually, FEL's operate in the so-called classical regime where quantum effects can be neglected. Recent developments in accelerator and laser physics permit the realization of a FEL in the quantum regime. We discuss the effects emerging in a quantum FEL by considering the time evolution of the density operator of the system.

Q 30.2 We 14:15 A 320

On-demand positioning of a preselected quantum emitter on a fiber-coupled toroidal microresonator — Markus Gregor, •Rico Henze, Tim Schröder, and Oliver Benson — AG Nanooptik, Institut für Physik, Humboldt-Universität zu Berlin, Hausvogteiplatz 5-7, 10117 Berlin

Toroidal microresonators are a valuable system to study cavity quantum electrodynamic (cQED) effects due to their high Q factors and small mode volume. It is particularly interesting to couple single quantum emitters to these cavities in order to investigate their potential for applications in quantum information processing. We present here a novel technique which uses tapered optical fibers to manipulate and transfer a preselected diamond nanocrystal onto such microcavities. Optical coupling of few nitrogen vacancy (NV) color centers contained inside the nanocrystal to the resonator modes is demonstrated by detecting the fluorescence via a tapered optical fiber coupler. A clear antibunching in the photon correlation measurement is observed indicating emission from only six NV centers residing inside the nanocrystal. The latter is confirmed by a photoluminescence spectrum at liquid helium temperature resolving individual zero phonon lines.

Q 30.3 We 14:30 A 320

Non-perturbative 2-photon Compton scattering from a circularly polarized laser — •Daniel Seipt and Burkhard Kämpfer — Forschungszentrum Dresden-Rossendorf, PF 510119, 01314 Dresden, Germany

An electron, moving in a strong laser field, emits photons. The Furry picture with Volkov states and propagators allows for a non-perturbative treatment of multi-photon laser-electron interactions. While the 1-photon emission has a classical analog [1], the 2-photon emission (double Compton effect) is a pure quantum effect, where the two photons have a certain degree of polarization entanglement. At low laser intensity one recovers [2], while at high laser intensity ($a_0 \gtrsim 1$) strong-field effects become important. These will be quantified in the talk, thus extending [3].

[1] T. Heinzl, D. Seipt, B. Kämpfer, `arXiv: 0911.1622v2`, (2009) [2] F. Mandl, T. H. R. Skyrme, Proc. Roy. Soc. A **215** 497, (1952). [3] E. Lötstedt, U. Jentschura, Phys. Rev. Lett. 103, 110404 (2009).

Q 30.4 We 14:45 A 320

A matterless double-slit — •Ben King, Antonino Di Piazza, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Quantum electrodynamics predicts that photons can interact with one another non-linearly in vacuum. When the intensity of the corresponding electromagnetic fields is sufficiently large, the macroscopic effect of this miniscule cross-section becomes measurable [1]. We demonstrate how a scenario, in which photons from a probe laser are scattered by two, strongly-focused, ultra-intense laser beams, can be regarded as a novel double-slit experiment, devoid of material constituents. It is shown that with the next generation of strong lasers, one can in principle measure the corresponding diffraction pattern [2].

[1] V. B. Berestetskii, L. P. Pitaevskii, E.M. Lifshitz, Quantum Electrodynamics, (Butterworth-Heinemann, 1996)

[2] B. King, A. Di Piazza, C. H. Keitel, Nature Photonics (in press).

Q 30.5 We 15:00 A 320

Towards the experimental realisation of an ideal quantum measurement — •Jürgen Volz, Roger Gehr, Guilhem Dubois, Jérôme Estève, and Jakob Reichel — Laboratoire Kastler-Brossel de l'ENS, 24 rue Lhomond, Paris, France

Error free qubit readout is one of the key ingredient to quantum information processing. In the case of atomic qubits, such as ions or neutral atoms, the most effcient methods rely on measuring the response of the qubit to an optical excitation. Using resonant light, as in the shelving technique, or far off resonance illumination, all these techniques are intrinsically destructive in the sense that at least one spontaneous emission is required to infer the qubit state. In this Letter, we demonstrate a cavity assisted qubit detection scheme that enables us to detect the qubit state with almost no photon scattering. We use the fact the atom-cavity system lies in the strong coupling regime, where depending on the internal atomic state we either observe a large or almost zero cavity transmission. Therefore, the role of spontaneous emission is replaced by cavity transmission carrying the necessary information for the state readout. Our results show that with this method we induce three times less scattering than possible a perfect free-space detector for the same detection error.

Q 30.6 We 15:15 A 320

Measurement of Arbitrary-Order Coherences in a Single Light Beam with two Polarizations — •Uwe Schilling[1], Joachim von Zanthier[1], and Girish S. Agarwal[2] — [1]Institut für Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Erlangen, Germany — [2]Department of Physics, Oklahoma State University, Stillwater, Oklahoma 74078-3072, USA

We present a scheme which allows to measure N-th order coherences of two orthogonally polarized light fields in a single spatial mode at very limited experimental costs. We show that to implement such a measurement, it is sufficient to determine N-th order *intensity moments* after the light beam has passed through two quarter-wave plates, one half-wave plate, and a polarizing beam splitter for specific settings of the wave plates. This method can be applied for arbitrarily large N and we give a set of explicit values for the settings of the wave plates, constituting an optimal measurement of the N-th order coherences for any N. While the most interesting application may be a full state tomography of Fock states, one can utilize our method for arbitrary (classical and nonclassical) states; in fact the general concepts are not even limited to polarization optics.

Q 30.7 We 15:30 A 320

A new paradigm for non-locality by many single photon emitters - violations of locality for visibility less than 50% — •Ralph Wiegner[1], Christoph Thiel[1], Joachim von Zanthier[1], and Girish S. Agarwal[2] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, 91058 Erlangen, Germany — [2]Department of Physics, Oklahoma State University, Stillwater, Oklahoma 74078-3072, USA

We investigate the spatial intensity-intensity correlations in the fluorescence light of multiple single-photon emitters and demonstrate that these correlations may violate locality. As it turns out, for $N > 2$ emitters, the widely-used CHSH inequalities are not suitable to prove the non-local character of the correlations. We therefore derive a new inequality, based on a Bell-Wigner-type inequality, of the form

$$0 \leq x_1 x_4 - x_1 x_2 - x_1 x_3 + x_2 x_3$$

which holds for $0 \leq x_1, x_2, x_3 \leq x_4 \leq 1$. Using this inequality, we demonstrate the non-local character of the correlations even for a visibility of the signal below 50%. Our results apply to a wide variety of single photon emitters like trapped ions, quantum dots, molecules and nitrogen vacancies in diamonds.

Q 30.8 We 15:45 A 320

Quantum displacement detection with a beam of paired photons — Martin Ostermeyer and •Carsten Henkel — Universität Potsdam, Germany

Light beams with strong correlations in the transverse plane, be they classical or quantum, can improve the resolution of optical images and even lead to novel concepts ("ghost imaging"). We discuss here the application of correlated photon pairs for the precision detection of the transverse displacement of a beam. The photon pairs can be produced with spontaneous parametric down-conversion and have EPR-like correlations in their positions and momenta. A non-classical regime is available where correlation lengths are below the diffraction limit [1]. We discuss the quantum noise limits for the beam displacement with a split detector scheme [2], both with and without the requirement of coincident photon detection.

[1] M. Ostermeyer, D. Korn, D. Puhlmann, C. Henkel, J. Eisert, J. mod. Opt. 56 (2009) 1829
[2] C. Fabre, J. B. Fouet, A. Maître, Opt. Lett. 25 (2000) 76; M. T. L. Hsu, V. Delaubert. P. K. Lam, W. P. Bowen, J. Opt. B 6 (2004) 495