Q 9: Quanteneffekte: Interferenz und Korrelationen

Time: Monday 14:00–16:15 Location: V7.01

Q 9.1 Mon 14:00 V7.01

Superradiance from entangled atoms — Ralph Wiegner[1], •Joachim von Zanthier[1], and Girish Agarwal[2] — [1]Institut für Optik, Information und Photonik, Universität Erlangen-Nürnberg, Erlangen — [2]Department of Physics, Oklahoma State University, Stillwater, USA

The progress in the preparation of entangled emitters, particularly in chains of trapped ions, opens the way to investigate new aspects of optics. For example, one could ask how the radiative properties of atoms in entangled states differ from those of atoms prepared in separable states. We consider a system of N independent atoms with an interatomic distance much larger than the emission wavelength prepared in well characterized entangled states and discuss their far-field radiation pattern. We show that the entangled state displays enhanced spontaneous emission and trace this enhancement back to interferences of multiple photon quantum path ways [1]. This framework is especially useful as separable initially excited states obviously do not display interferences at the level of the mean radiated intensity as their dipole moment is zero. The considered entangled states have also zero dipole moment. However the quantum path framework which is not based on the dipole moment can physically explain the enhanced radiation where a classical antenna interpretation is not applicable.

[1] R. Wiegner, J. von Zanthier, and G. S. Agarwal, Phys. Rev A 84, 023805 (2011).

Q 9.2 Mon 14:15 V7.01

Theory of coloured photon counting — •Elena del Valle[1], Alejandro Gonzalez-Tudela[2], Fabrice P. Laussy[3], and Michael J. Hartmann[1] — [1]Technische Universität München, Germany — [2]Universidad Autónoma de Madrid, Spain — [3]Walter Schottky Institut, München, Germany

Experimentally, the study of correlations between peaks of photoluminescence spectra is common practice in cavity-QED systems [1]. This provides valuable information about the dynamics of the bare and dressed states (polaritons), especially in out-of-equilibrium systems [2], where polaritons may not be well defined and the spectra may become too complex. However an adequate theoretical description of this powerful experimental procedure is still lacking. Frequency resolved correlation functions are, indeed, difficult to obtain theoretically and have received very little attention up to now [3].

We develop a general theory of frequency and time resolved correlation functions valid for steady state situations under continuous excitation or for the decay dynamics after pulsed excitation. We apply our theory to different fundamental cases such as resonance fluorescence (Mollow triplet), coupled modes (Rabi doublet) or two-photon emission from a quantum dot in a microcavity [4] providing predictions and guidance for the experiments.

[1] Hennessy et al., Nature 445, 896 (2007). [2] Laussy et al., PRL 101, 083601 (2008); del Valle & Laussy. PRL 105, 233601 (2010). [3] Joosten & Nienhuis, J. Opt. B 2, 158 (2000); Bel & Brown, PRL 102, 018303 (2009). [4] del Valle et al., NJP 13, 113014 (2011).

Q 9.3 Mon 14:30 V7.01

Topologically protected strongly correlated states of photons — •Mikhail Pletyukhov[1], Matous Ringel[2], Vladimir Yudson[3], and Vladimir Gritsev[2] — [1]Institut für Theorie der statistischen Physik, RWTH Aachen, Physikzentrum, D - 52074 Aachen — [2]Physics Department, University of Fribourg, Chemin du Musee 3, 1700 Fribourg, Switzerland — [3]Institute of Spectroscopy, Troitsk, Russia

Recent progress in fabricating hybrid optical nanostructures allowed engineering novel interesting states of light. We show that using certain nanostructures one can create strongly correlated states of photons in a controllable way. They are protected by a topological character of the chiral edge propagation which is possible in certain photonic crystals. The properties of these states are discussed in this talk.

Q 9.4 Mon 14:45 V7.01

Cavity-QED of a leaky planar resonator with an atom and an input single-photon pulse — •Denis Gonta[1,2] and Peter van Loock[1,2] — [1]Institut of Optik, Information und Photonik, Friedrich-Alexander-Universität Erlangen-Nürnberg, Staudtstrasse 7, 91058 Erlangen — [2]Optical Quantum Information Theory Group, Max Planck Institute for the Science of Light, Günther-Scharowsky-Str. 1, Bau 26, D-91058 Erlangen

In contrast to the dynamics of an atom-light interface in free space that is governed by a multi-mode interaction of an atom with the surrounding electromagnetic vacuum, the dynamics of a cavity-QED system can be characterized by just three parameters, (i) atom-cavity coupling strength (vacuum Rabi splitting) g, (ii) cavity relaxation rate κ, and (iii) atomic decay rate into the non-cavity modes γ. In the case of an atom inserted into a planar cavity with an input beam coupled to the resonator from the outside, it has been shown that these three parameters (g, κ, γ) are determined not only by the cavity quality factor and the strength of atom-cavity-reservoir coupling, but also by the lateral profile of the input beam [1]. We extend the setup of [1] and determine the cavity-QED parameters of a coupled system of atom, planar (leaky) cavity, and input single-photon pulse as functions of the lateral profile of the pulse. We confirm also that the radiative photon loss into the non-cavity modes can be suppressed by engineering appropriately the lateral profile of the input single-photon pulse.

[1] K. Koshino, Phys. Rev. A 73, 053814 (2006).

Q 9.5 Mon 15:00 V7.01

Signatures of single site addressability in resonance fluorescence spectra — •Peter Degenfeld-Schonburg, Elena del Valle, and Michael J. Hartmann — Technische Universität München, Physik Department I, James Franck Str., 85748 Garching, Germany

Pioneering methods in recent optical lattice experiments allow to focus laser beams down to a spot size that is comparable to the lattice constant. Inspired by this achievement, we examine the resonance fluorescence spectra of two-level atoms positioned in adjacent lattice sites and compare the case where the laser hits only one atom (single site addressing) with cases where several atoms are illuminated. In contrast to the case where the laser hits several atoms, the spectrum for single site addressing is no longer symmetric around the laser frequency. The shape of the spectrum of fluorescent light can therefore serve as a test for single site addressing. The effects we find can be attributed to a dipole-dipole interaction between the atoms due to mutual exchange of photons. Additionally we report on a more general relation between symmetric steady state power spectra and master equations which are symmetric under the exchange of particles.

Q 9.6 Mon 15:15 V7.01

Enhanced lifetime of positronium atoms via collective radiative effects — •Ni Cui, Mihai Macovei, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Positronium (Ps) is a hydrogen-like atom comprised of an electron and the positron. The ground states of Ps are not stable and the system will annihilate by γ emission. Such short lifetimes give rise to evident difficulties in accumulating Ps atoms and achieving Ps BEC, and the simulated annihilation from Ps BEC may set up a route towards a γ-ray laser [1]. Hereby, we proposed a method to manipulate the annihilation dynamics of a dense gas of Ps atoms employing superradiant and subradiant spontaneous emission. The annihilation dynamics can be controlled by the density of the gas and the intensity of the driving strong resonant laser field. We found that the annihilation lifetime of an ensemble of Ps atoms can be enhanced more than hundred times by trapping the atoms in the excited state via collective radiative effects in the resonant laser and cavity fields [2].

[1] P. M. Platzman and A. P. Mills, Jr., Phys. Rev. B 49, 454 (1994); D. B. Cassidy, *et al.* Phys. Rev. Lett. 106, 023401 (2011).

[2] Ni Cui, Mihai Macovei, Karen Z. Hatsagortsyan, and Christoph H. Keitel, arXiv:1112.1621v1.

Q 9.7 Mon 15:30 V7.01

Numerical realizations of optical centroid measurements — •Qurrat Ul-Ain and Jörg Evers — Max-Planck-Institut für Kernphysik, Heidelberg, Germany

Optical imaging methods are typically restricted to a resolution of order of the probing light wavelength λ by the Rayleigh diffraction limit. This limit can be circumvented by making use of correlated N-photon

states, having an effective wavelength λ/N. But the required N-photon detection usually renders these schemes unfeasible. In [1], an imaging scheme is proposed that replaces the multi-photon detectors by an array of single-photon detectors. It has been predicted in [1] that using a post-processing of the measured data, the resolution scaling of λ/N can be achieved for certain states of light. We aim at extending the approach to a broader class of input states, at finding optimum detection strategies, and at quantitatively studying the approach. For this, complementary to the existing approximate analytical results, we explore the approach using "experimental" data obtained from numerical experiments by sampling detection events from the initial state wave function. We analyze the resolution in dependence on the detector size to find optimum parameters for an experimental implementation. We also find indications that the scheme might work for a broader class of states than predicted based on the analytical estimates.

[1] M. Tsang, Phys. Rev. Lett., **102**, 253601 (2009).

Q 9.8 Mon 15:45 V7.01

Photon statistics at the transition from amplified spontaneous emission (ASE) to stimulated emission — •Sébastien Hartmann, Martin Blazek, and Wolfgang Elsässer — Institute of Applied Physics, TU Darmstadt, Germany

The intensity correlations $g^{(2)}(\tau)$ of photonics beams are governed by the nature of the photon emission process. Whereas laser light originating from stimulated emission events exhibits $g^{(2)}(0)=1$, spectrally broadband thermal light originating from spontaneous emission exhibits enhanced correlations with $g^{(2)}(0)=2$, reflecting photon bunching. Ingredients of both, spontaneous and stimulated emission processes, are present in the ASE emitted by superluminescent diodes (SLD). In ASE, spontaneously emitted photons experience a moderate amplification by stimulated emission, resulting in particularly interesting intensity correlations. Recently, it has been demonstrated that the intensity correlations of light emitted by SLDs can be tuned from thermal, i.e. $g^{(2)}(0)=2$ to nearly laserlike, i.e. $g^{(2)}(0)=1.33$ by increasing the spectral gain of the device [1]. Here, we comprehensively study this transition from ASE to stimulated emission, by applying optical feedback onto the SLD. Thus, we provide a deeper inside in the delicate emission state hierarchy in ASE sources.

[1] M. Blazek, S. Hartmann, A. Molitor and W. Elsäßer, "Unifying intensity noise and second-order coherence properties of amplified spontaneous emission sources", Optics Letters, Vol. 36, Issue 17, pp. 3455-3457 (2011)

Q 9.9 Mon 16:00 V7.01

On the feasibility of a nuclear exciton laser — •Nicolai ten Brinke and Ralf Schützhold — Fakultät für Physik, Universität Duisburg-Essen, Lotharstraße 1, D-47057 Duisburg, Germany

Nuclear excitons known from Mössbauer spectroscopy describe coherent excitations of a large number of nuclei – analogous to Dicke states (or Dicke super-radiance) in quantum optics. In this talk, we discuss the possibility of constructing a laser based on these coherent excitations. In contrast to the free electron laser (in its usual design), such a device would be based on stimulated emission and thus might offer certain advantages, e.g., regarding energy-momentum accuracy.