Q 54: Quantum Effects: QED

Time: Thursday 14:30–16:00 Location: SCH A01

Q 54.1 Thu 14:30 SCH A01

Observation of squeezed light with one atom — alexei ourjoumtsev, alexander kubanek, markus koch, christian sames, pepijn pinkse, gerhard rempe, and •karim murr — Max-Planck-Institut fuer Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

For a coherent or vacuum state of the electromagnetic field, the quantum uncertainties of its fluctuating electric and magnetic components are equal and minimize the Heisenberg's uncertainty relation. It is nowadays possible to reduce the value of one of the uncertainties below the vacuum level at the expense of increasing the other. Such "squeezed" states are so far generated using macroscopic media only, such as atomic vapours, optical fibres or non-linear crystals.

That a single atom can produce squeezed light has been predicted almost 30 years ago by Walls and Zoller. However, it has been foreseen by Mandel in 1982 that the squeezing generated by one atom would be "at least an order of magnitude more difficult" to observe than antibunching. Despite experimental efforts, single-atom squeezing has escaped observation.

We observe squeezed near-infrared light generated by a single neutral atom trapped inside a high-finesse optical cavity. With an excitation beam containing on average only 2 photons per system's lifetime, the measured field quadratures clearly present a phase-dependent nonclassical response. I will discuss the history on the theory of single-atom squeezing as well as our experiment for a broad audience.

Q 54.2 Thu 14:45 SCH A01

Observation of time-dependent, third-order correlations in cavity QED — •Markus Koch, Christian Sames, Maximilian Balbach, Haytham Chibani, Alexander Kubanek, Tatjana Wilk, Karim Murr, and Gerhard Rempe — Max-Planck-Institut für Quantenoptik, Hans-Kopfermann-Str. 1, 85748 Garching

A single two-level atom strongly coupled to a high-finesse cavity is a text book example of a dissipative quantum system, ideally suited to study fundamental effects of light-matter interaction. We probe its dynamics by evaluating time-dependent correlation functions of the light that is emitted from the system when it is driven by a probe beam. We present measurements of the second-order correlation function showing both vacuum Rabi oscillations, i.e. the coherent exchange of single photons between the atom and the cavity mode, and the coherent exchange of energy between the driving laser and the coupled atom-cavity system. Furthermore, we introduce third-order correlation functions as a new tool to observe effects involving the correlated emission of three photons. We find evidence for the coherent emission and reabsorption of single photons in the presence of another photon and show that the fluctuations of the transmitted intensity are asymmetric in time.

Q 54.3 Thu 15:00 SCH A01

Observation of the Collective Lambshift in Single-Photon Superradiance — •Ralf Röhlsberger[1], Kai Schlage[1], Balaram Sahoo[1], Sebastien Couet[2], and Rudolf Rüffer[3] — [1]DESY, Notkestr. 85, 22607 Hamburg — [2]KU Leuven, Celestijnenlaan 200D, 3001 Leuven, Belgium — [3]ESRF, 38043 Grenoble Cedex, France

The interaction of many identical two-level atoms with a common radiation field leads to a profound modification of the temporal, directional and spectral characteristics of their collective emission compared to that of a single atom. A prominent example is the phenomenon of superradiance that manifests as a strong acceleration of the collective spontaneous emission [1]. Later it was predicted that the superradiant emission goes along with a radiative shift of the transition energy, the collective Lamb shift (CLS) [2,3]. In the optical regime, however, this shift appeared to be extremely difficult to observe due to its small magnitude and atom-atom interactions masking it. In the x-ray regime, these effects can be neglected. Thus, we used pulsed 14.4 keV synchrotron radiation to resonantly excite ensembles of ^{57}Fe Mössbauer atoms into a purely superradiant state [4]. For that purpose the atoms were embedded into a planar solid-state cavity. Spectral analysis of the cooperative emission revealed the CLS as predicted. Applications for the analysis of cooperative emission in general will be discussed.

[1] R. H. Dicke, Phys. Rev. 93, 99 (1954). [2] R. Friedberg, S. R. Hartmann, and J. T. Manassah, Phys. Rep. C 7, 101 (1973). [3] M. O. Scully, Phys. Rev. Lett. 102, 143601 (2009). [4] R. Röhlsberger, K. Schlage, B. Sahoo, S. Couet and R. Rüffer, Science 328, 1248 (2010).

Q 54.4 Thu 15:15 SCH A01

Temperature invariance of Casimir–Polder potentials — •Stefan Yoshi Buhmann[1], Simen Ådnøy Ellingsen[2], and Stefan Scheel[1] — [1]Quantum Optics and Laser Science, Blackett Laboratory, Imperial College London, Prince Consort Road, London SW7 2AZ, United Kingdom — [2]Department of Energy and Process Engineering, Norwegian University of Science and Technology, N-7491 Trondheim, Norway

It is commonly assumed that thermal photons have an impact on the Casimir–Polder interaction of an atom with a surface. In particular, one would expect the potential of molecules or Rydberg atoms with low-frequency transitions to be very sensitive to temperature changes, because the thermal photon number for such transitions is very large even at room temperature.

In contrast to these expectations, we demonstrate that the potential of an atom in an energy eigenstate at nonretarded distance from a metal surface is temperature-invariant over the whole range from zero to room temperature and beyond [1]. As demonstrated for an infinite plate, this is due to strong cancellations of contributions from virtual and evanescent photons, leaving a temperature-invariant total potential. We are able to prove that more generally, temperature-invariance holds for metal bodies for arbitrary shapes [2].

[1] S. Å. Ellingsen, S. Y. Buhmann and S. Scheel, Phys. Rev. Lett. **104**, 223003 (2010).

[2] S. Y. Buhmann, S. Å. Ellingsen and S. Scheel, in preparation (2010).

Q 54.5 Thu 15:30 SCH A01

Theory of the QFEL — •Paul Preiss[1,2], Matthias Knobl[2], Roland Sauerbrey[1], and Wolfgang P. Schleich[2] — [1]Forschungszentrum Dresden-Rossendorf, 01314 Dresden, Germany — [2]Institut für Quantenphysik, Universität Ulm, 89069 Ulm, Germany

Having served as a coherent light source with a widely tunable wave length the free-electron laser has become interesting for theoratical physicists once more. New developments in accelerator and laser physics raise hope for the so-called QFEL, a free-electron laser operating in the quantum mechanical regime, e. g. at the Research Center Rossendorf in Dresden.

We develop a fully quantized one-particle theory for the dynamics of the interaction between the electron and the wiggler and laser field. Our results obtained for the quantum mechanical regime are reminiscent of dynamics in two-level systems. Compared to such a two-level system with one internal degree of freedom (e. g. an atom with a ground and one excited state) the state of our system is mainly determined by the momentum of the electron in the co-moving Bambini-Renieri frame. In contrast to the classical regime here the electron propagating through the wiggler field can only emit or absorb one single photon. Transitions including the emission or absorption of many photons are significantly suppressed.

Q 54.6 Thu 15:45 SCH A01

Feynman diagrams for dispersion interactions — •Harald Haakh, Juergen Schiefele, and Carsten Henkel — Institut für Physik und Astronomie, Universität Potsdam, Germany

Diagrammatic techniques have been used for a long time in perturbative calculations of dispersion interactions between atoms or molecules such as the Casimir-Polder or van-der-Waals interaction [1] and atomic (or molecular) QED, as in the Lamb shift and the calculation of radiative lifetimes. Using the multipolar coupling scheme and Feynman-ordered diagrams rather than retarded graphs, significantly reduces the number of graphs required for calculating the T-matrix. The formalism presented in Ref. [2] offers a rich toolbox that can be applied to different situations reaching from few-body interactions to Bose-Einstein condensates. It is possible to include macroscopic bodies and atomic wave packets, relevant for quantum gases in modern microtraps. Interesting applications involve entangled states or systems out of thermal equilibrium. Resonant contributions arise from the interaction of excited molecules and are supposed to play an important role in molecular biology [3].

[1] D.P. Craig and T. Thirunamachandran, Molecular Quantum Electrodynamics (Dover, 1998)

[2] J. Schiefele and C. Henkel, Phys. Rev. A **82**, 023605 (2010), J. Schiefele and C. Henkel, Phys. Lett. A (2010), doi:10.1016/j.physleta.2010.11.058, arXiv:1011.4428,

[3] H. Fröhlich, Proc. Nat. Acad. Sci. USA **72**, 4211 (1975).