Q 11: Quanteneffekte (QED)

Zeit: Montag 14:00–16:00 Raum: 5E

Gruppenbericht Q 11.1 Mo 14:00 5E

Observing the quantum jumps of light: birth and death of a photon in a cavity — •Stefan Kuhr[1,2], Sébastien Gleyzes[2], Christine Guerlin[2], Julien Bernu[2], Ulrich Hoff[2], Michel Brune[2], Jean-Michel Raimond[2], and Serge Haroche[2,3] — [1]Institut für Physik, Johannes Gutenberg Universität, Staudingerweg 7, D-55128 Mainz — [2]LKB, Ecole Normale Supérieure, 24 rue Lhomond, F-75231 Paris Cedex 05 — [3]Collège de France, 11 place Marcelin Berthelot, F-75231 Paris Cedex 05

A microscopic system under continuous observation exhibits at random times sudden jumps between its states. Quantum jumps of trapped massive particles (electrons, ions or molecules) have already been observed, which is not the case of the jumps of light quanta. Here we report on the first observation of photon number quantum jumps [1]. Microwave photons are stored in a superconducting cavity for times in the second range [2]. They are repeatedly probed by a stream of non-absorbing atoms. An atom interferometer measures the atomic dipole phase shift induced by the non-resonant cavity field, so that the final atom state reveals directly the presence of a single photon in the cavity. Sequences of hundreds of atoms highly correlated in the same state, are interrupted by sudden state-switchings. These telegraphic signals record, for the first time, the birth, life and death of individual photons.

[1] S. Gleyzes *et al.*, Nature (to be published), quant-ph/0612031.
[2] S. Kuhr *et al.*, quant-ph/0612138.

Q 11.2 Mo 14:30 5E

An analogy to Cavity QED in scattering-induced modal coupling in a microsphere resonator — •Andrea Mazzei[1], Leonardo Menezes[2], Stephan Götzinger[3], Vahid Sandoghdar[3], and Oliver Benson[1] — [1]Humboldt Universität zu Berlin - AG Nanooptik, Hausvogteiplatz 5-7, 10117 Berlin — [2]Departamento de Fìsica, Universidade Federal de Pernambuco, Brazil — [3]Laboratory of Physical Chemistry, ETH Zürich - Switzerland

The basic system to study in Cavity QED is a single dipole emitter interacting with a single mode of an optical cavity. In a coupled system with damping, two main regimes can be distinguished: in the *strong coupling regime* the dynamics between, e.g. an atom and a cavity, is reversible: Rabi oscillations and mode splitting are observed. In the *weak coupling regime* the interaction with a continuum of states results in an irreversible decay of the dipole. In this paper we introduce an analogy between CQED effects (atom and cavity) and the modal coupling of high-Q modes in an optical microresonator induced by a Rayleigh scatterer. In our experiments a scanning probe is used as a controllable Rayleigh scatterer, which can be positioned with nanometer precision in the whispering-gallery modes of a microsphere resonator. By moving the scanning probe into the mode, the modal coupling constant can be controlled and the transition from weak to strong coupling was observed: the resonance splits into a doublet, with a frequency splitting proportional to the coupling rate. The developed theoretical analogy gives also an explanation for the surprisingly large modal splitting previously reported by other groups.

Q 11.3 Mo 14:45 5E

Signatures of the Unruh effect from electrons accelerated by ultra-strong laser fields — •Ralf Schuetzhold[1], Gernot Schaller[1], and Dietrich Habs[2] — [1]Institut für Theoretische Physik, Technische Universität Dresden, 01062 Dresden, Germany — [2]Department für Physik der Ludwig-Maximilians-Universität München und Maier-Leibnitz-Laboratorium, Am Coulombwall 1, 85748 Garching, Germany

We calculate the radiation resulting from the Unruh effect for strongly accelerated electrons and show that the photons are created in pairs whose polarizations are perfectly correlated. Apart from the photon statistics, this quantum radiation can further be discriminated from the classical (Larmor) radiation via the different spectral and angular distributions. The signatures of the Unruh effect become significant if the external electromagnetic field accelerating the electrons is not too far below the Schwinger limit and might be observable with future facilities. Finally, the corrections due to the birefringent nature of the QED vacuum at such ultra-high fields are discussed.

Q 11.4 Mo 15:00 5E

Body-assisted van der Waals interaction between two atoms — •Hassan Safari[1], Stefan Yoshi Buhmann[1], Dirk-Gunnar Welsch[1], and Ho Trung Dung[2] — [1]Theoretisch-Physicalisches Institut, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, 07743 Jena, Germany — [2]Institute of Physics, Academy of Sciences and Technology, 1 Mac Dinh Chi Street, District 1, Ho Chi Minh City, Vietnam

It is well known that the vacuum fluctuations of the electromagnetic field can cause an interaction between electrically neutral, but polarizable particles, commonly referred to as the van der Waals (vdW) interaction. When the two atoms are not in free space, but placed within a nontrivial magnetoelectric environment, then the vdW interaction can be substantially modified.

Using fourth-order perturbation theory, a general formula for the vdW interaction potential between two neutral, electrically polarizable, ground-state atoms in the presence of an arbitrary arrangement of magnetoelectric bodies is derived. The theory is applied to two atoms in the presence of a planar multilayer system (with special emphasis on the perfectly reflecting plate and half space) and in the presence of a sphere. It is shown that in the nonretarded limit, the modification of the vdW interaction due to the presence of a perfectly reflecting plate can be understood by using the method of image charges.

Q 11.5 Mo 15:15 5E

Light-by-light diffraction — •Antonino Di Piazza, Karen Z. Hatsagortsyan, and Christoph H. Keitel — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

The influence of a strong optical standing wave into the propagation of an x-ray probe is calculated in the framework of nonlinear quantum electrodynamics. It is shown that the procedure usually followed, to assign to vacuum a refractive index different from unit due to vacuum polarization effects, is a too crude approximation because of the tight focusing of the strong field. After the interaction a linearly polarized x-ray probe becomes elliptically polarized with the main axis of the ellipse rotated with respect to the initial polarization direction. The obtained ellipticity and the polarization rotation angle are shown to be in principle measurable [1].

[1] A. Di Piazza, K. Z. Hatsagortsyan, and C. H. Keitel, Phys. Rev. Lett. **97**, 083603 (2006). See also hep-ph/0602039.

Q 11.6 Mo 15:30 5E

Temperature dependence of the Casimir-vdWaals potential — •Lodewijk Arntzen — arntzen@physi.uni-heidelberg.de

The temperature dependence of the Casimir-vdWaals potential will be discussed. For the system He-Si, the Casimir-vdWaals potential is explicitly calculated using a model for the polarizability of the helium atom, and a model for the dielectric function of silicon. Experimental access is obtained with the Atomic Beam Spin Echo (ABSE) spectrometer by quantum reflecting cold ^{3}He atoms from a Si(111) surface. The temperature of the surface is varied between 300K and 1200K. It is found that the quantum reflectivity drops approximately with a factor 3 in this temperature range. It is shown that a potential term proportional to T and r^{-3} is needed to describe the data, and its value is compared with the zero frequency term from the Lifshitz theory.

Q 11.7 Mo 15:45 5E

Dynamical theory of Casimir-Polder forces — •Stefan Yoshi Buhmann and Dirk-Gunnar Welsch — Theoretisch-Physikalisches Institut, Friedrich-Schiller-Universität Jena, Max-Wien-Platz 1, 07743 Jena

The Casimir-Polder force experienced by a single atom in the presence of magnetoelectric bodies is a well-known consequence of QED. In contrast to the common static approaches often used to study forces on ground-state atoms, we employ a genuinely time-dependent approach in order to account for the nontrivial dynamics arising for initially excited atoms. Starting from the operator-valued Lorentz force, a general formula for the dynamical Casimir-Polder force is presented, which can be further evaluated by solving the coupled atom-field dynamics.

For weak coupling the Markov approximation can be used to show

that the Casimir-Polder force on an initially excited atom can be written as a linear combination of components whose dynamics follows that of the associated atomic density-matrix elements. Strong atom-field coupling may arise if an atom near-resonantly interacts with a narrow quasimode of the body-assisted electromagnetic field, leading to a reversible exchange of excitation between the atom and the field mode. Assuming that the atom-mode system initially shares a single excitation, it is found that the resulting Casimir-Polder force undergoes damped Rabi oscillations, where both amplitude and mean value of the oscillations depend on the initial state.