Q 4: Quanteneffekte: QED

Time: Monday 10:30–12:30 Location: V7.01

Q 4.1 Mon 10:30 V7.01

Quantum reservoir engineering of photon states — •Christian Arenz[1], Cecilia Cormick[1], David Vitali[2], and Giovanna Morigi[1] — [1]Universität des Saarlandes — [2]Universit'a di Camerino

The coupling of a quantum system to its surrounding environment leads to dissipation and decoherence. Its was shown, however, that under appropriate „engineering“ of the coupling between system and environment, the environment can also be used as a resource for preparing the system in a target non-classical state, which is the steady state of the coupled dynamics [1,2,3,4].

In this talk we present a protocol for creating an entangled state of two modes of a high-finesse microwave cavity by using a beam of atoms. We „engineer“ the coupling between the atoms and the two modes by means of classical fields and obtain a Lindblad-type of master equation for the cavity modes. We show that the dynamics this equation describes can drive the system into a unique asymptotic states, that is the desired entangled state. The feasibility of the protocol is discussed considering the effect of cavity and atomic decay.

[1] F. Verstraete, M.W. Michael and J.I Cirac, Nature Phys. 5, 633 (2009).
[2] J.F. Poyatos, J.I Cirac and P. Zoller, Phys. Rev. Lett. 77, 4728 (1996).
[3] S. Pielawa, G. Morigi, D. Vitali and L. Davidovich, Rev. Lett 98, 240401 (2010).
[4] S. Diehl, A. Micheli, A. Kantian, B. Kraus, H.P. Büchler and P. Zoller, Nature Phys. 4, 878 (2008).

Q 4.2 Mon 10:45 V7.01

Lasing with one-emitter — •Fabrice P. Laussy[1], Elena del Valle[2], and Jonathan J. Finley[1] — [1]Walter Schottky Institut, München, Germany — [2]Technische Universität München, Germany

We revisit the one-atom laser, where optical coherence grows thanks to a single emitter in strong-coupling with a cavity field. We identify a new regime where the emission of uncorrelated photons is retained even without stimulated emission. We provide the conditions for this and prove analytically that a field coherent to all orders is generated even for small and vanishing intensities, bringing a new light to thresholdless lasing. We analyse the crossover between this regime and the one established by stimulated emission and show that a universal transition–independent of the energy scales–occurs when going from the quantum to the classical regime, where the quantization picture breaks down, giving rise to a new type of Mollow triplet.

[1] Laussy, del Valle and Finley, arXiv:1106.0509.
[2] del Valle and Laussy, Phys. Rev. A, 84:043816, 2011.
[3] del Valle and Laussy, Phys. Rev. Lett., 105:233601, 2010.

Q 4.3 Mon 11:00 V7.01

Nonlinear Double Compton Scattering in pulsed plane wave fields — •Felix Mackenroth and Antonino Di Piazza — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

Nonlinear Double Compton Scattering (NDCS) is the emission of two photons by an electron scattered in a strong laser field [1] which cannot be accounted for perturbatively. In the framework of QED this process can occur with an off-shell ($p^2 \neq m^2$) or on-shell electron between the two emissions. The former process has no classical analogue while in the latter case the process is split up into two incoherent Nonlinear Compton Scattering events. We show that by dropping the usual assumption of a monochromatic laser field, the dressed propagator of the intermediate electron naturally splits up into an on- and off-shell part and is finite without the need for ad-hoc regularization [2]. Furthermore recently a quantum treatment of radiation reaction was presented taking into account only incoherent photon emissions and neglecting the coherent processes [3]. By comparing the two contributions to NDCS we explore the validity of this approximation.

[1] E. Lötstedt and U.D. Jentschura, Phys. Rev. Lett. **103**, 110404 (2009).
[2] F. Mackenroth and A. Di Piazza, in preparation.
[3] A. Di Piazza, K. Z. Hatsagortsyan and C. H. Keitel, Phys. Rev. Lett. **105**, 220403 (2010).

Q 4.4 Mon 11:15 V7.01

Quantum electron self-interaction in a strong laser field — •Sebastian Meuren and Antonino Di Piazza — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg

The quantum states of an electron in a plane-wave field are known as Volkov states [1]. In [2] we have calculated the electron states in a plane wave by including at leading order the effects of the interaction of the electron with its own electromagnetic field (self interaction) by solving the Schwinger-Dirac equation in the presence of an arbitrary linearly-polarized plane-wave field (see Ref. [3]). The expression of the modified Volkov states first shows that self-effects lead to quantum modifications of the electron quasi-momentum in a monochromatic plane-wave. They are qualitatively different from the well known classical part of the quasi-momentum which can be understood from the quivering motion of the electron. Moreover, we have shown that the spin dynamics of the electron is significantly altered by taking the self-interaction into account. We have indicated that an electron initially prepared in a definite spin state may undergo a spin-flip while passing through a strong laser field only due to the interaction with its own electromagnetic field and even if it does not radiate photons.

[1] V. B. Berestetskii, E. M. Lifshitz, and L. P. Pitaevskii, Quantum Electrodynamics, (Elsevier, Amsterdam, 1982)
[2] S. Meuren and A. Di Piazza, Phys. Rev. Lett., in press.
[3] V. I. Ritus, J. Sov. Laser Res. **6**, 497 (1985).

Q 4.5 Mon 11:30 V7.01

Semiclassical theory of self-organization of atoms in optical cavities — •Stefan Schütz[1], Hessam Habibian[1,2], and Giovanna Morigi[1] — [1]Theoretische Physik, Universität des Saarlandes, D-66041 Saarbrücken, Germany — [2]Grup d'Óptica, Universitat Autònoma de Barcelona, E-08193 Bellaterra, Barcelona, Spain

We theoretically study the formation of self-organized structures of atoms, whose dipolar transition is driven by a laser and also couples to the optical mode of a high-finesse cavity. Self-organization in the cavity field emerges due to the mechanical forces of the cavity photons on the atoms, whereby the cavity field is sustained by the photons scattered by the atoms from the laser and hence depends on the atomic position. We consider the semiclassical model in [1], which is used in order to describe the onset on self-organization, and identify the limits of validity. From the Fokker-Planck equation in [1] we derive a numerical model, from which we study self-organization for various parameters and number of atoms. We compare our findings with the results in [2], finding full agreement. In addition, we discuss the effects of shot noise on the dynamics of self-organization.

[1] P. Domokos et al., J. Phys. B: At. Mol. Opt. Phys. **34** 187-198 (2001)
[2] J. K. Asbóth, P. Domokos, H. Ritsch, and A. Vukics, Phys. Rev. A **72**, 053417 (2005)

Q 4.6 Mon 11:45 V7.01

Quantum well cavity QED with squeezed light — Eyob A. Sete[1], •Sumanta Das[1], and Hichem Eleuch[2] — [1]Department of Physics, Texas A&M University, College Station, TX 77843, USA — [2]Max Planck Institute for the Physics of Complex Systems, Nöthnitzer Strasse 38, D-01187 Dresden, Germany

Recently, the effect of a nonresonant strong drive on the intersubband excitonic transition has been investigated and observation of Autler-Townes doublets was reported [1,2]. In light of these new results, an eminent question of interest is: How does the quantum nature of radiation emitted from a quantum well (QW) in a micro-cavity get affected in the presence of a squeezed light source and non-resonant drive? We investigate this here. We consider a semiconductor QW in a microcavity driven by coherent light and coupled to a squeezed light source. The source can be in form of a squeezed vacuum reservoir or a subthreshold optical parametric down converter. We also include exciton-exciton scattering in our analysis. In the strong-coupling and low excitation regimes, we study the intensity spectrum and the squeezing spectrum [3].

[1] J. F. Dynes, *et. al.* Phys. Rev. Lett. **94**, 157403 (2005).
[2] M. Wagner, *et. al.* Phys. Rev. Lett. **105**, 167401 (2010).
[3] E. A. Sete, S. Das and H. Eleuch, Phys. Rev. A **83**, 023822 (2011).

Q 4.7 Mon 12:00 V7.01

Non-perturbative two-photon Compton scattering in pulsed laser fields — •Daniel Seipt and Burkhard Kämpfer — Helmholtz-Zentrum Dresden-Rossendorf

In relativistically strong laser fields with intensities well above 10^{19} W/cm^{-2}, multi-photon emission processes are important in collisions of relativistic electron beams with the laser pulse. We present results on the coherent two-photon process (double Compton scattering) in the presence of strong and short laser pulses, taking into account the finite temporal pulse length exactly for the first time.

Q 4.8 Mon 12:15 V7.01

Nonthermal fixed points, scaling of an ultracold bose gas — •Nikolai Philipp[1,2] and Thomas Gasenzer[1,2] — [1]Institut für Theoretische Physik, Ruprecht-Karls-Universität Heidelberg, Philosophenweg 16, 69120 Heidelberg — [2]ExtreMe Matter Institute EMMI, GSI Helmholtzzentrum für Schwerionenforschung GmbH, Planckstraße 1, 64291 Darmstadt, Germany

Turbulent scaling phenomena are studied in an ultracold Bose gas away from thermal equilibrium. Fixed points of the dynamical evolution are characterized in terms of universal scaling exponents of correlation functions. The scaling behavior is determined analytically in the framework of quantum field theory, using a nonperturbative approximation of the two-particle irreducible effective action as well functional flow equations for proper correlation functions. Anomalously large exponents arise in the infrared regime of the turbulence spectrum which recently were demonstrated to be related to the appearance of topological excitations of the superfluid. We compute the power-law exponents in the framework of the Wetterich functional renormalisation group equation and compare with previously obtained results.