Q 2: QED

Time: Monday 11:00–13:00 Location: HS 1015

Q 2.1 Mon 11:00 HS 1015

Quantum optics without quantum paradoxes — •Falk Rühl — Auf der Alm 14, 52159 Roetgen, Germany

A transition from the directed one./.one interaction model, mediated by quanta, to a symmetrical any./.any interaction model, mediated by EM-waves propagating in $\mathbb{R}^3$, allows a paradox-free explanation of all effects observed in quantum optical experiments.

In a detection model based on an any./.any interpretation, the total energies of weakly bound electrons in a detector are driven to a continuous random walk, by the local superposition of the EM-fields of all sources of radiation. In the rare instance, where a random walk approaches the binding energy, even extremely weak superadded pulses of EM-radiation, e.g. received from distant sources under investigation, can trigger an event-like release of an electron, that carries the binding energy. Suitably scaled, the count rate $r(a)$, as a function of the power $a \geq 0$, absorbed from the source illumination, has the asymptotic linear branches $r(a) \geq \max\{0, a+d-1\}$, that are connected by a smooth transition in the "tunnel regime" around $d+a=1$. The absorption of amplitude-/phase-modulated radiation is resonantly enhanced only, if the radiation drives closed cycles in the rotating frames of the detecting oscillators, which makes only a small subset of the continuously evolving and radiating "beable" states of sources also "observable".

The "late quantization", the result of a resonant radiation./.target interaction, eliminates "quantum jumps", and all quantum transport paradoxes, that have their roots in the futile attempt to base the interpretation on an "early quantization" of the sources.

Q 2.2 Mon 11:15 HS 1015

Correlations of the Quantum Vacuum in a Nontrivial Analogue Spacetime — •Cristofero Oglialoro[1], Frieder Lindel[2], Fabian Spallek[1], and Stefan Yoshi Buhmann[1] — [1]University of Kassel, Germany — [2]University of Freiburg, Germany

A fascinating aspect of quantum mechanics is that it predicts non-vanishing fluctuations in the electromagnetic ground state. Despite many macroscopic effects being attributed to this fluctuating vacuum field, it has only recently become possible to measure these fluctuations directly via electro-optic sampling. This allowed to access the two-point correlation function of the vacuum field at distinct spacetime regions and to study its spacetime structure [1]. The formalism of macroscopic quantum electrodynamics serves to describe field propagation within nonlinear dispersive media theoretically and predicts the traces of the quantum vacuum in the electro-optic sampling signal and its spacetime structure [2]. In this framework, we discuss how additional external fields alter the spacetime structure of the sampled vacuum fluctuations by interpreting the effects of the external field as a nontrivial analogue spacetime.

[1] F. F. Settembrini, et al., Nat. Commun. 13, 3383 (2022).
[2] F. Lindel, et al., Phys. Rev. A 102, 041701(R) (2020).

Q 2.3 Mon 11:30 HS 1015

Quantum radiation in a dielectric with time-dependent dissipation — •Sascha Lang[1,2,3], Stefan Yoshi Buhmann[1], Ralf Schützhold[2,4,3], and William G. Unruh[5] — [1]University of Kassel, Germany — [2]Helmholtz-Zentrum Dresden-Rossendorf, Germany — [3]Universität Duisburg-Essen, Germany — [4]Technische Universität Dresden, Germany — [5]University of British Columbia, Canada

Rapidly changing system parameters in tuneable dielectrics can trigger the spontaneous conversion of quantum vacuum fluctuations into real photons [1]. A famous example is the production of photon pairs in the presence of strongly non-adiabatic refractive index modulations $n(t)$. Unlike in relativistic quantum field theory, the evolution of quantum vacuum fluctuations in dielectrics is affected by dispersion and dissipation. A consistent description of the quantum dynamics in explicitly time dependent environments requires a microscopic model that can be quantised canonically.

We present an approach which models the medium via a continuous set of harmonic oscillators [2] and accounts for dissipation by coupling those medium oscillators to a scalar environment field [3]. As an example of quantum radiation, we consider particle pair creation in a medium with a non-adiabatically varying dissipation strength.

[1] F. Belgiorno, S. L. Cacciatori & F. Dalla Piazza: Eur. Phys. J. D **68**, 134 (2014)
[2] Hopfield, Phys. Rev. **112**, 1555 (1958)
[3] Lang, Schützhold & Unruh: Phys. Rev. D 102, 125020 (2020)

Q 2.4 Mon 11:45 HS 1015

Numerical evaluation of Casimir-Lifshitz forces in the time domain — •Carles Martí Farràs[1], Philip Kristensen[2,3], Bettina Beverungen[1], Francesco Intravaia[1], and Kurt Busch[1,4] — [1]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik & Photonik, Newtonstr. 15, 12489 Berlin, Germany — [2]DTU Electro, Technical University of Denmark, Lyngby, Denmark — [3]NanoPhoton - Center for Nanophotonics, Technical University of Denmark, Lyngby, Denmark — [4]Max Born Institute, Berlin, Germany

Fluctuation-induced phenomena, stemming from both quantum and thermal fluctuations, which are inherent in nature, exhibit fascinating effects that become particularly relevant at short-length scales. A notable example is the Casimir effect, which describes a usually attractive force between electrically neutral macroscopic objects. Apart from their fundamental interest, a comprehensive understanding of such interactions is crucial for the progress of nanostructured device development. Since analytical calculations are only possible for a few highly symmetric geometries, this has prompted the development of methods to numerically evaluate Casimir forces in the context of complex geometries and material models. Here, we present a time-domain finite-element-based numerical approach leveraging the capabilities of the discontinuous Galerkin time-domain (DGTD) method. It allows to accurately assess the electromagnetic response of the system, providing a robust and efficient framework for systematically evaluating Casimir forces in a wide range of configurations.

Q 2.5 Mon 12:00 HS 1015

Redfield-pseudomodes theory — •Felix Riesterer, Lucas Weitzel Dutra Souto, Andreas Buchleitner, and Dominik Lentrodt — University of Freiburg, Freiburg, Germany

Quantum systems which are strongly coupled to a large environment or a bath are difficult to tackle theoretically, since common approximations such as weak-coupling Master equations break down in this regime. A commonly used concept to circumvent this difficulty is to include the bath degrees of freedom responsible for the strong coupling into the system. This idea underlies a whole family of approaches known as pseudomodes theory, whose most well-known representative is the open Jaynes-Cummings model in cavity quantum electrodynamics. In general, pseudomodes are an approach to describe the dynamics of open quantum systems where instead of tracing out the complete environment, discrete auxiliary modes featuring Lindbladian loss are retained in the system. We present a generalized pseudomodes concept which allows for a more general Markovian loss described by a Redfield equation. We then apply the generalized Redfield-pseudomodes approach within the framework of cavity quantum electrodynamics. In particular, we derive a pseudomodes expansion of the spectral density, which has to be matched with the original continuum theory to guarantee the equivalence of the Redfield-pseudomodes representation. We then compare the fitting capability of the generalized mode expansion of the spectral density to that of the corresponding expansion of the in the Lindblad-pseudomodes representation for different exemplary cavity geometries, demonstrating a significantly improved convergence.

Q 2.6 Mon 12:15 HS 1015

Heat transport using nonreciprocal media — •Nico Strauss, Omar Jesús Franca Santiago, and Stefan Yoshi Buhmann — Institute of Physics, University of Kassel, 34132 Kassel, Germany

The second law of thermodynamics dictates that heat flows from warm to cold objects, thereby providing a direction of time [2]. In the optics of nonreciprocal media [1], an arrow of time is alternatively provided by the observation that optical paths cannot be reversed. How are these two notions compatible at the level of quantum electrodynamics? In order to answer this question, we calculate the nanoscale heat transfer between the surfaces of two planar nonreciprocal media, namely topological insulators which exhibit a temperature difference $\Delta T = T_1 - T_2$. We analyse the impact of the nonreciprocal properties of the two plates on the heat transfer and investigate their interplay with the second law in the near-field regime.

[1] S. Y. Buhmann et al., New J. Phys. **14**, 083034 (2012).
[2] Volokitin, A. I.; Persson, B. N. J. Rev. Mod. Phys. **4**, 79 (2007).

Q 2.7 Mon 12:30 HS 1015

Quantum free-electron laser: single- and multiphoton transitions — •Peter Kling[1] and Enno Giese[2] — [1]Deutsches Zentrum für Luft- und Raumfahrt e.V. (DLR), Institut für Quantentechnologien, Wilhelm-Runge-Straße 10, 89081 Ulm, Deutschland — [2]Technische Universität Darmstadt, Fachbereich Physik, Institut für Angewandte Physik, Schlossgartenstr. 7, 64289 Darmstadt, Deutschland

The quantum free-electron laser (“Quantum FEL”) is a proposed x-ray source. In contrast to existing devices (“classical FEL”), where an electron in the undulator follows continuous trajectories and emits many photons, an electron in the Quantum FEL occupies only two resonant levels on a discrete momentum ladder and emits at most one photon. We investigate the influence of multiphoton corrections [1] on the dynamics of the electron and on the photon statistics of the emitted radiation. Moreover, we (i) try to identify the challenges for an experimental realization [2] and (ii) study the transition between classical and quantum regime in the FEL from a fundamental point of view [3].

[1] P. Kling, E. Giese, Phys. Rev. Research 5, 033057 (2023).
[2] A. Debus et al., Phys. Scr. 94, 074001 (2019).
[3] C. M. Carmesin et al., Phys. Rev. Research 2, 023027 (2020).

Q 2.8 Mon 12:45 HS 1015

Dicke-like superradiance of distant noninteracting atoms — •Manuel Bojer and Joachim von Zanthier — Friedrich-Alexander-Universität Erlangen-Nürnberg, Quantum Optics and Quantum Information, Staudtstr. 1, 91058 Erlangen, Germany

Fully excited two-level atoms separated by less than the transition wavelength cooperatively emit light in a short burst, a phenomenon called superradiance by R. Dicke in 1954 [Phys. Rev. 93, 99 (1954)]. The burst is characterized by a maximum intensity scaling with the square of the number of atoms N and a temporal width reduced by N compared to the single atom spontaneous decay time. Both effects are usually attributed to a synchronization of the electric dipole moments of the atoms occurring during the process of light emission. Contrary to this explanation, it was recently shown by use of a quantum path description that the peak intensity results from the quantum correlations among the atoms when occupying symmetric Dicke states. Here we investigate from this perspective the temporal evolution of the ensemble, starting in the small sample limit, i.e., when the atoms have mutual separations much smaller than the transition wavelength λ and pass down the ladder of symmetric Dicke states. In addition, we explore the temporal evolution for the case of distant noninteracting atoms with mutual separations much larger than λ. We show that in this case a similar superradiant burst of the emitted radiation is observed if the quantum correlations of the atoms are generated by conditional photon measurements retaining the atomic ensemble within or close to the symmetric subspace.