Q 10: Quantum Effects: QED II

Time: Monday 17:00–18:30 Location: P 4

Q 10.1 Mon 17:00 P 4

Ab-Initio Description of Photoinduced Processes Beyond Classical Maxwell Theory — •Norah Hoffmann, Christian Schaefer, Heiko Appel, and Angel Rubio — Max Planck Institute for the Structure and Dynamics of Matter, Hamburg, Germany

In common methods for the ab-initio description of photoinduced processes such as the visual process, photosynthesis or solar cells, typically the classical Maxwell's equations are employed to describe the propagation of light. The applicability of these equations has been demonstrated since decades for a wide range of physical phenomena and parameter regimes. However, considering the ultimate limit of single molecules interacting with a few photons, the classical description of the electromagnetic field does not suffice anymore. In this case the quantum nature of the electromagnetic field has to be taken into account and therefore existing ab-initio approaches have to be extended. In the present work we face the question: Whether and what changes in the analysis and simulation of photoinduced processes by going beyond the classical Maxwell description. Here the idea of exact factorization, introduced for electron-nuclear problems, will be generalized to electron-photon systems, by considering the recently established multi scale implementation of the Maxwell-equations in the octopus code as Ehrenfest limit for quantum electrodynamics. We apply our novel approach to spontaneous and stimulated emission for atoms and molecules in optical cavities and investigate laser pulses with orbital-angular momentum to address recent experiments with chiral light.

Q 10.2 Mon 17:15 P 4

Coulomb interaction in generic environments — •Pablo Barcellona, Robert Bennett, and Stefan Yoshi Buhmann — Institute of Physics, Albert-Ludwigs University of Freiburg

We consider the the Coulomb force between two point charges in general environments, constituted by magnetodielectric bodies. The environment is taken into account via the classical Green tensor. We describe the interaction as arising from the exchange of one photon between the pair of charges, using time-independent perturbation theory. Screening for spatially-dispersive media, polarization effects for non-translationally invariant systems and local-field corrections are included and discussed. In the limit of dilute polarizable media we recover the interaction between a charged particle and a polarizable molecule.

Q 10.3 Mon 17:30 P 4

Van der Waals interaction at finite temperature — •Helge Dobbertin[1], Pablo Barcellona[2], Manuel Donaire[3], Stefan Yoshi Buhmann[2], and Stefan Scheel[1] — [1]Institut für Physik, Universität Rostock, Albert-Einstein-Straße 23, 18059 Rostock, Germany — [2]Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg, Germany — [3]Laboratoire Kastler Brossel, ENS-CNRS-UPMC et Collège de France, 4 place Jussieu, 75252 Paris, France

Dispersion forces such as van der Waals forces originate from electromagnetic field fluctuations, both quantum and thermal. One would expect a significant influence of the thermal fluctuations, e.g. in thermal vapors of Rydberg atoms, where strong van der Waals interactions have been demonstrated [1]. On the other hand, it is known that Rydberg dispersion interactions can become temperature-independent due to subtle cancellations [2]. Here, we present a general theory for the van der Waals interaction of excited atoms at finite temperature in the presence of macroscopic bodies within the framework of macroscopic quantum electrodynamics. We show limiting cases of high temperature and discuss under which conditions temperature dependence or independence can be expected.

[1] T. Baluktsian et al., Phys. Rev. Lett. **110**, 123001 (2013).
[2] S. Å. Ellingsen et al., Phys. Rev. A **84**, 060501(R) (2011).

Q 10.4 Mon 17:45 P 4

Semiclassical picture for electron-positron photoproduction in strong laser fields — •Sebastian Meuren, Christoph H. Keitel, and Antonino Di Piazza — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg

Inside a strong laser field electrons/positrons emit photons via nonlinear Compton scattering and photons decay into electron-positron pairs via the nonlinear Breit-Wheeler process [1]. Under certain circumstances a cascade of these fundamental processes develops and theoretical calculations become intricate. All known approaches, which are feasible in this regime, are based on the semiclassical approximation, which separates the classical propagation of the particles from the actual quantum transitions. Approximately, the latter happen instantaneously and essentially as if the external field were a constant-crossed field [2]. It was pointed out, e.g., in [3] that the standard approach is not capable of reproducing the details of the spectrum. In [4] we have shown that also the substructure of the spectrum is correctly described if the semiclassical approximation is applied on the amplitude rather than the probability level of a Feynman diagram.

[1] Di Piazza et al., Rev. Mod. Phys. **84**, 1177 (2012)

[2] V. I. Ritus, J. Sov. Laser Res. **6**, 497 (1985)

[3] C. N. Harvey et al., Phys. Rev. A **91**, 013822 (2015)

[4] SM, C. H. Keitel and A. Di Piazza, Phys. Rev. D **93**, 085028 (2016)

Q 10.5 Mon 18:00 P 4

Simulating strong control fields in nuclear quantum optics — Kilian P. Heeg[1], Andreas Kaldun[1], Cornelius Strom[2], Patrick Reiser[1], Johann Haber[2], Hans-Christian Wille[2], Stefan Goerttler[1], Rudolf Rüffer[3], Christoph H. Keitel[1], Ralf Röhlsberger[2], Thomas Pfeifer[1], and •Jörg Evers[1] — [1]Max-Planck-Institut für Kernphysik, Heidelberg, Germany — [2]Deutsches Elektronen-Synchrotron DESY, Hamburg, Germany — [3]ESRF-The European Synchrotron, Grenoble, France

X-ray quantum optics recently gained considerable momentum, both, theoretically and experimentally. However, a severe practical limitation arises from the fact that suitable strong control laser fields are generally not available. Even x-ray free electron lasers are expected to have only a moderate impact on the nuclei, mostly, due to their narrow line width as compared to the x-ray pulse bandwidth. To circumvent this problem, we are developing methods to simulate the effect of strong control fields in certain configurations, without the need to actually apply any electromagnetic field. In this talk, I will review our recent theoretical and experimental progress in this direction.

Q 10.6 Mon 18:15 P 4

Collective magnetic splitting in single-photon superradiance — •Xiangjin Kong and Adriana Pálffy — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg, Germany

In an ensemble of identical atoms, cooperative effects like superradiance may alter the decay rates and the transition energies may be shifted from the single-atom value by the so-called collective Lamb shift. While such effects in ensembles of two-level systems are well understood, realistic multi-level systems are more difficult to handle.

Here, we present a quantitative study of systems of atoms or nuclei under the action of an external magnetic field, where a collective contribution to the level shifts appears that can amount to seizable deviations from the single-atom Zeeman or magnetic hyperfine splitting. We develop a formalism to describe single-photon superradiance in multi-level systems and identify three parameter regimes, two of which present measurable deviations in the radiation spectrum compared to the case of single-atom magnetic-field-induced splitting [1]. Only one of these regimes has been so far confirmed experimentally in nuclear condensed-matter systems [2]. Finally, we show that all three regimes should be realizable in planar x-ray cavities with an embedded nuclear layer [3] under experimental parameters available today. Our findings give new and unexpected insights on the collective behaviour of optical and x-ray systems in magnetic fields.

[1] X. Kong and A. Pálffy, arXiv:1606.02988 (2016).
[2] R. Röhlsberger *et al.*, Nature 482, 199 (2012).
[3] X. Kong and A. Pálffy, Phys. Rev. Lett. 116, 197402 (2016).