Q 40: Quantum Effects (QED) I

Time: Wednesday 14:00–15:15 Location: S Ex 04 E-Tech

Q 40.1 Wed 14:00 S Ex 04 E-Tech

Strong-coupling of electrons and cavity-photons in an electron microscope — •Ofer Kfir and Claus Ropers — IV. Physics Institute, University of Göttingen, 37077 Göttingen, Germany

Inelastic scattering of electrons with a specimen, as investigated in electron microscopy, creates entanglement between the electron and the sample excitation, e,g., an electromagnetic mode [1]. Typically, fast dephasing makes this effect challenging to detect. For example, plasmonic modes, readily observable by electron light-scattering due to their high polarizability, suffer from substantial losses, and therefore, exhibit typical lifetimes of few femtoseconds. This prevents successive electrons in the electron microscope beam to interact with the same excitation.

Here, we propose transparent dielectric cavities as possible mediators for few-electron entanglement. Spontaneous and stimulated scattering processes are studied in a second-quantization model for the coupled electron and photon systems. The combination of high quality factors and long interaction lengths represents an attractive combination of sufficient coupling strength and long lifetime. Furthermore, electron-photon phase-matching may offer the possibility to reach conditions of strong coupling and high frequency selectivity.

[1] Schattschneider and Löffler, Ultramicroscopy 190, 39 (2018)

Q 40.2 Wed 14:15 S Ex 04 E-Tech

Spin effects in the laser fields — •Rashid Shaisultanov[1], Yan-Fei Li[2], Karen Z. Hatsagortsyan[1], Feng Wan[2], Jian-Xing Li[2], and Christoph H. Keitel[1] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117, Heidelberg, Germany — [2]School of Science, Xi'an Jiaotong University, Xi'an 710049, China

We study spin effects in the laser fields with the photon emission taken into account. The probability of photon emission by an electron for arbitrary polarization of all particles is obtained by means of quasiclassical operator method. We apply the obtained results to study the spin dynamics of electrons in interaction with an ultraintense laser pulse.

Q 40.3 Wed 14:30 S Ex 04 E-Tech

Semi-classical limitations for photon emission in strong external fields — •Erez Raicher[1], Shalom Eliezer[2,3], Christoph H. Keitel[1], and Karen Z. Hatsagortsyan[1] — [1]Max Planck Institute for nuclear physics, Heidelberg, Germany — [2]Polytechnic University of Madrid, Madrid, Spain — [3]Soreq nuclear research center, Yavne, Israel

The semi-classical heuristic emission formula of Baier-Katkov [Sov. Phys. JETP 26, 854 (1968)] is well-known to describe radiation of an ultrarelativistic electron in strong external fields employing the electron's classical trajectory. To find the limitations of the Baier-Katkov approach, we investigate electron radiation in a strong rotating electric field quantum mechanically using the Wentzel-Kramers-Brillouin approximation. Except for an ultrarelativistic velocity, it is shown that an additional condition is required in order to recover the widely used semi-classical result. A violation of this condition leads to two consequences. First, it gives rise to qualitative discrepancy in harmonic spectra between the two approaches. Second, the quantum harmonic spectra are determined not only by the classical trajectory but also by the dispersion relation of the effective photons of the external field.

Q 40.4 Wed 14:45 S Ex 04 E-Tech

X-ray Quantum Frequency Conversion: Analysis and Future Applications — •Christina Boemer, Andreas Galler, and Christian Bressler — European XFEL GmbH Holzkoppel 4, 22869 Schenefeld, Germany

Nonlinear processes in the optical regime are well understood and applied extensively to study light matter interactions, unlike processes in the burgeoning field of x-ray quantum optics. In contrast to conventional nonlinearities the manifestation of hard x-ray nonlinearities differs in both theory and experiment. We investigate the nonlinear effect of parametric down-conversion (PDC) in the x-ray regime, in which an incident x-ray photon is spontaneously converted into a highly correlated photon pair, marking a most prominent example for x-ray quantum optics.

We present a structured analysis of the phase-matching parameter space for PDC in different materials. Furthermore, we have strong evidence that this quantum frequency conversion effect can be used as a local probe of valence electron properties. Possible future applications as a novel spectroscopic method or improved imaging technique are foreseen and presented.

Q 40.5 Wed 15:00 S Ex 04 E-Tech

FEL: Quantum Effects in Phase Space — •Moritz Carmesin[1,2], Peter Kling[2,1], Roland Sauerbrey[2], and Wolfgang P. Schleich[2,3] — [1]Helmholtz-Zentrum Dresden-Rossendorf, 01328 Dresden, Germany — [2]Institut für Quantenphysik and Center for Integrated Quantum Science and Technology (IQ^{ST}), Universität Ulm, 89069 Ulm, Germany — [3]Hagler Institute for Advanced Study, Institute for Quantum Science and Engineering (IQSE), and Texas A&M AgriLife Research, Texas A&M University, College Station, TX 77843-4242, USA

A free-electron laser (FEL) is usually considered a classical device since its dynamics can be fully described within classical electrodynamics. The reason for this fact is the parameter regime wherein the state-of-the-art devices operate. However, there exists a quantum regime [1, 2], where a quantum mechanical model of the process is definitely required.

Starting from a quantum mechanical description of the FEL within Wigner phase space, we trace back the emergence of quantum effects depending on specific parameters, e. g. the strength of the fields, or the initial momentum spread compared to the quantum mechanical recoil.

[1] P. Kling et al. 2015 *New J. Phys.* **17** 123019
[2] R. Bonifacio et al. 2006 *Phys. Rev. AB* **9** 090701