Q 39: Quantum effects: Light scattering and propagation

Time: Wednesday 14:00–16:00 Location: F 342

Q 39.1 Wed 14:00 F 342

Diffractionless image propagation without absorption — •LIDA ZHANG and JÖRG EVERS — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, D-69117 Heidelberg, Germany

Recently, Firstenberg et al. have proposed and experimentally demonstrated a novel method to eliminate diffraction of a probe field carrying an arbitrary image in a thermal atomic medium[1,2]. Their method takes advantage of the thermal atomic motion and collisions. Control fields are applied such that momentum space components of the probe beam exhibits stronger coupling to the atoms moving in the opposite direction such that they are effectively carried back towards the main axis. But while this method eliminates the diffraction of the probe field, it necessarily involves strong absorption, and therefore is impractical.

Here we propose an enhanced scheme in which images encoded onto a probe field can be propagated diffractionless without absorption. An additional incoherent pump field is employed which together with the coupling fields generates additional atomic coherences such that gain is established for the probe. This way, the absorption of the probe due to single-photon absorption can be compensated by the gain. Based on this setup, prospects for various applications are discussed.

[1] O. Firstenberg, M. Shuker, N. Davidson, and A. Ron, Phys. Rev. Lett. 102, 043601 (2009).

[2] O. Firstenberg, P. London, M. Shuker, A. Ron and N. Davidson, Nature Phys. 5, 665 (2009).

Q 39.2 Wed 14:15 F 342

Conservation of Energy in Coherent Backscattering of Light — •ANGELIKA KNOTHE and THOMAS WELLENS — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg

We investigate the phenomenon of coherent backscattering of light, an interference effect that is observed when light propagates in disordered media in the presence of a boundary interface. Up to this day, it is not yet well-known what are the processes that allow this effect to occur without violating the law of conservation of total energy. [1]

We analyze in detail the processes at the origin of coherent backscattering as well as their relation to the mechanism that gives rise to the effect of weak localization. In the frame of a full description treating jointly these interference effects in random media, we are able to provide an explanation of the mechanism ensuring energy conservation.

[1] S. Fiebig *et al.*, Europhys. Lett. **81** 64004 (2008)

Q 39.3 Wed 14:30 F 342

The Quantum Nature of Random Lasers — •REGINE FRANK — Institut für Theoretsiche Physik, Universität Tübingen

Within this talk we present quantitative theoretical results for the quantum coherence of random laser light. The coherence is derived within a closed framework of diagrammatic quantum field theory coupled to a laser rate equation system. Furthermore, it is demonstrated how the ratio between classical coherence and quantum coherence can be tuned by dissipation. Decoherence effects are responsible for the lasing spot diameter on the one hand, but it can be derived quantitatively how the quantum nature of random lasers suffers due to decoherence.

Q 39.4 Wed 14:45 F 342

Photon-photon scattering in collisions of laser pulses — •BEN KING[1] and CHRISTOPH H. KEITEL[2] — [1]Ludwig-Maximilians-Universität, Theresienstraße 37, 80333 München, Germany — [2]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

Motivated by recent interest in building higher-intensity laser facilities [1, 2], we investigate the possibility of measuring the predicted phenomenon of elastic vacuum photon-photon scattering with a single 10 PW optical laser beam split into two Gaussian-focused pulses with arbitrary impact geometry [3], extending previous work [4-5]. By calculating the number of photons scattered into regions of high signal-to-noise ratio, we find that the elastic process should be measurable with such a set-up, and if these pulses are sub-cycle, the frequency-shifting, vacuum four-wave mixing process could be measurable too.

[1] http://www.extreme-light-infrastructure.eu, Extreme Light Infrastructure (2012)

[2] http://www.xcels.iapras.ru, eXawatt Center for Extreme Light Studies (2012)

[3] B. King and C. H. Keitel, New J. Phys. **14**, 103002 (2012)

[4] B. King, A. Di Piazza and C. H. Keitel, Nature Photon. **4**, 92–94 (2010)

[5] A. Di Piazza, K. Z. Hatsagortsyan and C. H. Keitel, Phys. Rev. Lett. **97**, 083603 (2006)

Q 39.5 Wed 15:00 F 342

Nonlinear double Compton scattering in the full ultrarelativistic quantum regime — •FELIX MACKENROTH and ANTONINO DI PIAZZA — Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg

An electron scattered from a high-intensity laser field may emit more than one photon. The simplest effect of this type is the emission of two photons [1], labeled nonlinear double Compton scattering (NDCS). We present a detailed analysis of NDCS in an ultra-strong laser field taking the effects of the laser field into account exactly and allowing for an arbitrary temporal laser field shape. We put particular emphasis on the parameter regime where nonlinear and quantum effects such as photon recoil significantly affect the emission pattern. It is demonstrated that due to recoil the energies of the emitted photons are no longer independent. This dependence is explained in terms of a semiclassical model, based on the possibility of assigning separate classical trajectories to the electron in the laser field before and after each quantum photon emission [2]. By virtue of the developed model we identify an experimentally feasible detection scheme for NDCS in the full quantum regime. The accessibility of this regime with already available plasma-based electron accelerator and laser technology is demonstrated by a numerical analysis.

[1] E. Lötstedt and U.D. Jentschura, Phys. Rev. Lett. **103**, 110404 (2009).

[2] F. Mackenroth and A. Di Piazza, submitted (see arXiv:1208.3424).

Q 39.6 Wed 15:15 F 342

An optical diode made from a "moving" photonic crystal — •JÖRG EVERS[1,2], DA-WEI WANG[2,4], HAI-TAO ZHOU[2], MIAO-JUN GUO[2], JUN-XIANG ZHANG[2], and SHI-YAO ZHU[2,3,4] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Beijing Computational Science Research Centre, Beijing 100084, China — [3]State Key Laboratory of Quantum Optics and Quantum Optics Devices, Institute of Opto-Electronics, Shanxi University, Taiyuan 030006, China — [4]Centre of Optics Sciences and Department of Physics, The Chinese University of Hong Kong, Hong Kong, China

Optical diodes controlling the flow of light are of principal significance for optical information processing. They transmit light from an input to an output, but not in reverse direction. This breaking of time reversal symmetry is conventionally achieved via Faraday or non-linear effects. Here we propose an all-optical optical diode which requires neither magnetic fields nor strong input fields. It is based on a "moving" photonic crystal generated in a three-level electromagnetically-induced-transparency medium in which the refractive-index of a weak probe is modulated by the moving periodic intensity of a strong standing coupling field with two detuned counter-propagating components. Due to the Doppler effect, the frequency range of the crystal's band gap for the probe co-propagating with the moving crystal is shifted from that for the counter-propagating probe. This mechanism is experimentally demonstrated in a room temperature Cs vapour cell.

Q 39.7 Wed 15:30 F 342

Statistical Properties of Photons in the Ultrastrong Coupling Regime — •ALESSANDRO RIDOLFO[1], SALVATORE SAVASTA[2], and MICHAEL J. HARTMANN[1] — [1]Physik Department, Technische Universität München, James-Franck-Strasse, 85748 Garching, Germany — [2]Dipartimento di Fisica e Scienze della Terra, Universitá di Messina, Viale F. Stagno d'Alcontres 31, 98166 Messina, Italy

We present calculations for photon coincidence counting statistics in the ultrastrong coupling regime, where the strength of the interaction between an emitter and the cavity photons becomes comparable to the transition frequency of the emitter or the resonance frequency of the cavity mode. In such a regime of interaction, the usual normal order correlation functions fail to describe the output photon statistics. Exploiting the correct input-output relations within a suitable Master Equation approach, we are able to propose correlation functions that are valid for arbitrary degrees of light-matter interaction. In particular, here we focus on the photon blockade effect [1] and the emission of non-classical light from thermal systems [2], whose standard scenario is significantly modified for ultrastrong coupling.

[1] A. Ridolfo, M. Leib, S. Savasta, and M.J. Hartmann, Phys. Rev. Lett. 109, 193602 (2012)

[2] A. Ridolfo, S. Savasta, and M.J. Hartmann, arXiv:1212.1280 (2012)

Q 39.8 Wed 15:45 F 342

Coherent backscattering of intense laser light by cold Sr atoms - a diagrammatic pump-probe approach — •Andreas Ketterer, Vyacheslav Shatokhin, and Andreas Buchleitner — Physikalisches Institut Albert-Ludwigs-Universität Freiburg, Germany

The diagrammatic pump-probe approach is a promising method to study coherent transport of intense laser light in cold atomic clouds [1]. It expresses the multiple scattering signal in terms of single atom responses, and thus avoids the problem of the exponential growth of the Hilbert space dimension with an increasing number of atoms. In this talk we will show how to construct arbitrary single-atom building blocks for atoms with internal degeneracy, and present numerical results for triple scattering from Sr atoms.

[1] T. Wellens et al., Phys. Rev. A **82**, 013832 (2010)