Q 19: Quantum effects: Light scattering and propagation

Time: Tuesday 10:30–12:15 Location: DO26 208

Q 19.1 Tue 10:30 DO26 208

Utilizing Nonlinearities in Mie-scattering Systems — •Andreas Lubatsch[1] and Regine Frank[2] — [1]Electrical Engineering, Precision Engineering, Information Technology, Georg-Simon-Ohm University of Applied Sciences, Kesslerplatz 12, 90489 Nürnberg, Germany — [2]Institute for Theoretical Physics, Eberhard-Karls University Tübingen, Germany Center for Light-Matter-Interaction, Sensors and Analytics (LISA+) and Center for Complex Quantum Phenomena (CQ)

We present theoretical considerations of systems of spherical Mie semiconductor scatterers. The scatterers display nonlinear characteristics in the optical spectrum and they are embedded in a matrix which exhibits also nonlinear response properties. We discuss the influence of these various non-linearities on the response to ultra-short pump pulses. We focus especially on higher order Mie-resonances and their interplay with nonlinear response properties of the system. We consider Kerr non-linearities and also frequency conversion with and without optical gain. The possibilities of utilizing this behavior in applications are discussed.

G. Maret, T. Sperling, W. Buehrer, A. Lubatsch, R. Frank, C.M. Aegerter, Nature Photonics 7,934 (2013); R. Frank, Appl. Phys. B (2013) 113:41 (2013); R. Frank, A. Lubatsch,Phys. Rev. A, 84,013814 (2011);

Q 19.2 Tue 10:45 DO26 208

Self-protected polariton states in photonic quantum metamaterials — •Matteo Biondi[1], Sebastian Schmidt[1], Gianni Blatter[1], and Hakan E. Türeci[1,2] — [1]ETH Zurich, Zürich, Switzerland — [2]Princeton University, Princeton, USA

We discuss the formation of polariton states in an open one-dimensional coupled cavity array containing a single qubit in its central site. Interestingly, the transmission through this quantum metamaterial exhibits two ultra-narrow resonances, corresponding to long-lived self-protected polaritonic states localized around the site containing the qubit (qubit-photon quasi-bound states). The lifetime of these states is found to increase exponentially with the number of array sites, thereby far simplifying the achievement of strong coupling in this architecture. The robustness of these states with respect to disorder is also investigated. The proposed setup is realizable with current state of the art circuit QED technology. Reference: arXiv:1309.2180

Q 19.3 Tue 11:00 DO26 208

Electromagnetic shock waves in the polarised quantum vacuum — •Patrick Böhl[1], Ben King[1,2], and Hartmut Ruhl[1] — [1]Ludwig-Maximilians-Universität, Theresienstraße 37, 80333 München, Germany — [2]Plymouth University, Drake Circus, Plymouth PL4 8AA, UK

Heisenberg's uncertainty principle allows for the existence of virtual electron-positron pairs in vacuum. As these states can interact with real photons, the vacuum can be polarised and act as a nonlinear medium, giving rise to quantum corrections to the classical Maxwell equations [1]. We have solved these modified equations numerically in $(1+1)$ dimensions and performed the first calculation of a collision of arbitrarily shaped pulses [2]. Taking the example of Gaussian pulses, we find from simulations and analytical calculations that if the interaction length and field strength are sufficiently large, the polarised vacuum can elicit shock waves [3], which accompany continuous frequency generation. These results could have implications in extreme astrophysical environments.

[1] B. King and C. H. Keitel, New J. Phys. **14**, 103002 (2012).
[2] H. Ruhl and N. Elkina, Proc. SPIE 8080, 80801P (2011).
[3] P. Böhl, B. King and H. Ruhl (in preparation).

Q 19.4 Tue 11:15 DO26 208

Theory of Anderson Localization of Light in Real World Disordered Samples — •Regine Frank[1] and Andreas Lubatsch[2] — [1]Institute for Theoretical Physics, Eberhard-Karls University Tübingen, Germany Center for Light-Matter-Interaction, Sensors and Analytics (LISA+) and Center for Complex Quantum Phenomena (CQ) — [2]Electrical Engineering, Precision Engineering, Information Technology, Georg-Simon-Ohm University of Applied Sciences, Kesslerplatz 12, 90489 Nürnberg, Germany

To derive Anderson localization of light is one of the holy grails of our time [1]. We show in this talk theoretical results derived by Vollhardt-Wölfle theory of photons[2,3,4] in 3D disordered, finite sized real world systems. Signatures of Anderson localized states are determined and they can be clearly distinguished from extended light-matter bound states as well as frequency converted photons and losses.

[1] T.Sperling et al., Nature Photon. 7, 48-52 (2013)
[2] G.Maret et al., Nature Photon. 7, 934-935 (2013)
[3] A.Lubatsch et al., Phys. Rev. B 71, 184201 (2005)
[4] R.Frank et al., Phys. Rev. B 73, 245107 (2006)

Q 19.5 Tue 11:30 DO26 208

Multiple scattering of light in optical fibers with a nanoscopic core — •Harald R. Haakh, Sanli Faez, and Vahid Sandoghdar — Max Planck Institut für die Physik des Lichts, Erlangen

Multiple scattering of light in reduced dimensions and particularly in waveguiding structures such as photonic crystal waveguides, has garnered interest lately both in experiment and theory as it may give rise to Anderson localized states and random cavity formation. We investigate the coupling of quantum scatterers to the fundamental mode of an optical fiber with a nanoscopic (or subwavelength) core as a versatile platform for the study of light transport through a one-dimensional multiply scattering medium. A rigorous theoretical treatment based on dyadic Green tensors allows for a careful analysis of the role of scattering into non-guided modes and its influence on the transport properties. Our results indicate the persistence of localized states under limited emitter-fiber coupling and may also be transferred to other waveguiding structures.

Q 19.6 Tue 11:45 DO26 208

Frequency Correlations in Reflection from a Random Medium — •Angelika Knothe and Thomas Wellens — Physikalisches Institut, Albert-Ludwigs-Universität Freiburg, Hermann-Herder-Str. 3, 79104 Freiburg

For the treatment of wave propagation in random media, a proper understanding of the interference effects that have impact on the average intensity is crucial. Well-known manifestations of such interference effects are coherent backscattering (enhancement of average backscattered intensity in backscattering direction) or weak localization (reduction of diffusion constant). In an earlier work [1], we studied the first order corrections to the average reflected intensity in an expansion in the disorder parameter $\frac{1}{k\ell}$ (k denotes the wave number, and ℓ stands for the scattering mean free path). In the present contribution, we focus on the properties of the frequency correlation function defined as the average product of two intensities reflected from a random scattering medium at different frequencies. As revealed by experiment [2], this correlation function proved to be much more sensitive to an increase of the disorder strength than the coherent backscattering cone, and undergoes a breakdown for larger values of $\frac{1}{k\ell}$ approaching the localization threshold. In order to obtain a better understanding of the experimental results, we include those scattering diagrams giving rise to the first order corrections in $\frac{1}{k\ell}$ in our theoretical treatment.

[1] A. Knothe and T. Wellens, J. Phys. A **46**, 315101 (2013)
[2] O. L. Muskens, T. van der Beek and A. Lagendijk, Phys. Rev. B **84**, 035106 (2011)

Q 19.7 Tue 12:00 DO26 208

High-frequency light reflector via low-frequency light control — •Jörg Evers[1,3], Da-Wei Wang[2], Shi-Yao Zhu[3], and Marlan O. Scully[2,4] — [1]Max-Planck-Institut für Kernphysik, Saupfercheckweg 1, 69117 Heidelberg — [2]Texas A&M University, College Station, TX 77843, USA — [3]Beijing Computational Science Research Centre, Beijing 100084, China, China — [4]Baylor University, Waco, TX 76706, USA

New approaches to control the flow of light are discussed, which can be operated at high frequencies where conventional optical elements are lacking. We show that high-order nonlinear light-matter interactions can selectively be induced in an electromagnetically induced transparency medium to effectively create a higher-order photonic bad gap structure. This way, the momentum of high-frequency light can be reversed via the atomic coherence created by a control field with substantially lower frequency, effectively forming a mirror. Both the backward retrieval of single photons and of continuous waves are analyzed. A proof-of-principle experiment with thermal ^{85}Rb vapor is proposed, and potential implementations at hard x-ray energies are discussed.

[1] Da-Wei Wang, Shi-Yao Zhu, Jörg Evers, Marlan O. Scully, arXiv:1305.3636 [physics.optics]