HL 27: Photonic crystals III

Time: Tuesday 16:00–19:00 Location: EW 203

HL 27.1 Tue 16:00 EW 203

Cherenkov radiation in photonic crystals — •Christian Kremers, Dmitry N. Chigrin, and Johann Kroha — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany

We have considered modifications of Cherenkov radiation mediated by a periodic dielectric function of a general three-dimensional photonic crystal [1]. Analytical solutions for electric and magnetic fields far from the trajectory of the moving charged particle have been derived as a Bloch mode expansion within the stationary phase approximation [2]. An asymptotic analysis of the Cherenkov far-field allows to generalize the Huygens principle, which provides a simple and intuitive picture of the spatial distribution of radiated field due to charged particle moving in a periodic medium. Consistent semi-analytical expressions have been obtained for the spatial and spectral distribution of the radiated power. We have also applied this method to the analysis of Cherenkov radiation in a two-dimensional photonic crystal. The spatial and spectral distribution of radiated power for different velocities of the charged particle have been substantiated by numerically rigorous finite-difference time-domain calculations.

[1] C. Luo, M. Ibanescu, S. G. Johnson, J. D. Joannopoulos, Science **299**, 368 (2003).
[2] D. N. Chigrin, Phys. Rev. E **70**, 056611 (2004).

HL 27.2 Tue 16:15 EW 203

Defocused Imaging of Single Emitters in Photonic Crystals — •Rebecca Wagner, Frank Cichos, and Sven Zimmermann — Molecular Nanophotonics Group, University of Leipzig, Linnéstraße 5, 04103 Leipzig

Photonic crystals are materials with a periodically varying dielectric constant. By multiple scattering of light on this spatially modulated refractive index a photonic band structure and photonic band gaps are introduced. Because of the spatial variation of the refractive index the optical density of states inside a photonic crystal is a local property too. Thus a local probe for the study of local optical properties is needed. So far this has only been achieved for 2D photonic structures by means of near field scanning microscopy. We introduce a new technique that uses single emitters inside 3D photonic crystals as probes for its local optical properties. Besides the spectral redistribution of their emission which can be observed in an altered emission spectrum there occurs also an angular redistribution. This anisotropic emission of the embedded emitters can be imaged by defocused fluorescence microscopy since it modifies their defocused imaging patterns. This is shown with extensive calculations and experimental studies. A fitting procedure is introduced to extract the angular dependence of the photonic stop band from the experimental results.

HL 27.3 Tue 16:30 EW 203

Efficiency optimization for constructing maximally localized Wannier functions — •Tobias Stollenwerk, Dmitry N. Chigrin, and Johann Kroha — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn, Germany

The Wannier function approach is well suited for the description of photonic crystal based structures. The efficiency of this approach crucially depends on the degree of localization of the Wannier functions in real space. Due to the phase indeterminacy of the Bloch functions the problem of obtaining maximally localized Wannier functions is reduced to the problem of finding an optimal set of phases and is an optimization problem in parameter space of large dimensionality. In that respect, questions like, definition of the locality criterion or the choice of the optimization method, are of great importance.

We have systematically analyzed maximally localized Wannier functions of two-dimensional square and triangular lattice photonic crystals for both fundamental polarizations. Two definitions of the locality criterion have been introduced, namely the integrated modulus in the first unit cell and the second moment of the Wannier function. We have used the standard conjugate gradient optimization scheme as well as a genetic algorithm based stochastic algorithm to solve the optimization problem. We report on "pros-and-cons" of the different locality criteria and optimization methods applied to the problem of constructing maximally localized Wannier functions in photonic crystals.

HL 27.4 Tue 16:45 EW 203

Retrieving angle dependent effective parameters of metamaterials — •Christoph Menzel[1], Thomas Paul[1], Carsten Rockstuhl[1], Thomas Pertsch[2], and Falk Lederer[1] — [1]Institut für Festkörpertheorie- und optik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, D-07743, Jena, Deutschland — [2]Institut für angewandte Physik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, D-07743, Jena, Deutschland

The retrieval of effective parameters of metamaterials (MM) can be made with various approaches. The most common employs the reflected and transmitted amplitude at a finite MM slab. Inverting the analytical expression for reflection and transmission at a slab composed of a homogenous isotropic media having an arbitrary permittivity and permeability, allows to solve for them. This technique, and all the other approaches, are employed up to now only for normal incidence; providing only insufficient insights into the MM properties. For example, applying MMs as a perfect lens requires them to have an angle independent effective permittivity and permeability of both being -1, which has yet to be elucidated. In this contribution we outline how to extend this algorithm to predict the effective properties as a function of the angle of incidence and the polarization. The necessary requirements and the assumptions on the media's properties are outlined. The algorithm is applied exemplarily to determine the angle dependent properties of a fishnet structure. The properties are investigated as a function of the number of layers the MM is made of.

HL 27.5 Tue 17:00 EW 203

The Goos-Hänchen and Imbert-Fedorov shift at metamaterial interfaces — •Thomas Paul, Christoph Menzel, Carsten Rockstuhl, and Falk Lederer — Institut für Festkörpertheorie und -optik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, D-07743, Jena, Deutschland

Illuminating an interface separating two half-spaces with a finite beam at an incident angle larger than the critical angle of total internal reflection causes the reflected beam to be translated in space when compared to the incident one. A longitudinal displacement is usually called the Goos-Hänchen shift, a transversal the Imbert-Fedorov shift. Here we will reveal the peculiarities that occur if the reflecting media is not a natural homogenous but an artificial nanostructured media. We investigate at first photonic crystals (PCs). We show that beam shifts observable at such media are deducible from the dispersion relation of the Bloch modes in the infinite PC. As the second part, we will investigate beam shifts at the interfaces of metamaterials (MM), where a simultaneous strong dispersion in the permittivity and permeability can occur in finite spectral domains. Independent of the particular media we investigate at first the necessary symmetry conditions of the beam that have to be met in order to observe any of the shifts or both simultaneously. We present rigorous calculations which are compared to predictions achieved from classical models, namely the Artmann- or the Renard model. We outline configurations which allow observing giant shifts in both geometries, where emphasis is put on a giant Imbert-Fedorov shift.

15 min. break

HL 27.6 Tue 17:30 EW 203

Anderson localization and correlation length in random lasers — •Regine Frank, Andreas Lubatsch, and Johann Kroha — Physikalisches Institut, Universität Bonn, Germany

We present a systematical theory for the interplay of strong localization effects and absorbtion or gain of classical waves in 3-dimensional, disordered dielectrics, which is based on a selfconsistent resummation of self-interference (Cooperon) contributions. In the presence of absorption or gain, Anderson localized modes do not exist in a strict sense. However, in the case of linear gain (i.e. exponential intensity growth), causality in connection with the Cooperon pole structure predicts the appearance of a new *finite* length scale, which we interpret as the coherence length ξ of a random laser mode. A characteristic dependence of ξ on the gain intensity is found, consistent with experiments. In addition, we solve the fully time dependent problem of the laser rate equations of a 4-level laser (i.e. non-linear gain), coupled to the random gain medium, where the transport of light in the random medium is treated by the self-consistent Cooperon resummation. The results are compared with our semianalytic calculations for the case of linear gain.

HL 27.7 Tue 17:45 EW 203

Lasing and selected physical Properties of Photonic Composites obtained by doping of Liquid Crytsals with Nanomaterials — •Wolfgang Haase and Fedor Podgornov — Eduard-Zintl-Institute for Inorganic and Physical Chemistry, Darmstadt University of Technology, Petersenst. 20, D 64287 Darmstadt

We will report on some physical properties obtained by doping of Liquid Crystals (LC)/Ferroelectric Liquid Crystals (FLC) with different Nanomaterials as are Single Walled Carbon Nanotubes (SWCNT), Titaniumdioxide, Bariumtitanate. Tunable Lasing on cholesteric-nematic Nanocomposites could be obtained. Several electrooptical properties as are switching time, spontaneous polarization will be reported. The dielectric spectra of FLC/SWCNT show remarkable reduction of the absorption intensity, this has been interpreted as due to trapping of ions/charges on the interface FLC/SWCNT.

HL 27.8 Tue 18:00 EW 203

Polaritonic band gaps in gold films covered with high-refractive index gratings — •Alexander Sprafke, Karl Weis, and Gero von Plessen — I. Institute of Physics (1A), RWTH Aachen University, 52056 Aachen, Germany

In structured noble-metal films, surface-plasmon polaritons (SPPs) can be excited optically. SPPs consist of electromagnetic surface waves accompanied by longitudinal electron-density waves. Polaritonic crystals made from planar metal films covered with dielectric gratings have been shown to exhibit band gaps in the plasmon-polariton dispersions. Here, we investigate the polaritonic band gaps of gold films coated with high-refractive index ($n > 2$) gratings. The dependence of the band-gap width on the refractive index and filling factor of the gratings is studied experimentally and theoretically. In particular, the ultimate limits on the band-gap width achievable in these structures are discussed.

HL 27.9 Tue 18:15 EW 203

Theory of light localization in absorbing, disordered photonic crystals — •Andreas Lubatsch, Regine Frank, and Johann Kroha — Physikalisches Institut, Universität Bonn, Germany

We discuss light propagation in three dimensional photonic crystals exhibiting both, disorder in the scattering strength and absorption effects. To calculate transport quantities such as the diffusion coefficient, we use a systematical, semi-analytical theory based on a self-consistent Cooperon resummation of scalar waves. The presented theory takes into account the bandstructure of the photonic crystal as well as the non-conserving properties of the medium. The non-critical quantities, representing the effective medium, are self-consistentently calculated in the coherent potential approximation (CPA).

HL 27.10 Tue 18:30 EW 203

Electromagnetic Green's dyadic: finite difference time domain formulation — •Dmitry Chigrin — Physikalisches Institut, Universitaet Bonn, Nussallee 12, D-53115 Bonn, Germany

The electromagnetic Green's function (dyadic) is a central object in many topics of theoretical and computational electrodynamics. The knowledge of the Green's function for a given medium provides directly information about, e.g., the radiation dynamics of excited atoms in this medium or scattering processes on the medium inhomogeneities. In the same time, the finite-difference time-domain method (FDTD) is known to be very powerful and popular numerical tool of computational electrodynamics. Being simple in implementation and numerically rigorous in nature this method suits very well for large scale electrodynamics problems. In this presentation, an extension of the FDTD method for direct calculation of the electromagnetic Green's function will be discussed. An appropriate choice of initial and boundary conditions will be considered. An application of the method to the study of the radiation dynamics of two-level atom in a finite two-dimensional photonic crystal will be presented.

HL 27.11 Tue 18:45 EW 203

On the dispersion relation of light in metamaterials — •Carsten Rockstuhl[1], Christoph Menzel[1], Thomas Paul[1], Thomas Pertsch[2], and Falk Lederer[1] — [1]Institut für Festkörpertheorie- und optik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, D-07743, Jena, Deutschland — [2]Institut für angewandte Physik, Friedrich-Schiller-Universität Jena, Max-Wien Platz 1, D-07743, Jena, Deutschland

The characterization of metamaterials (MM) is usually restricted to the determination of the effective parameters of a thin film at normal incidence. However, such information is of limited use as firstly, the parameters deduced from a thin film might differ from the bulk and secondly, the effective properties as encountered by a plane wave that propagates at an angle deviating from a crystallographic axis are not elucidated. Here will give an answer on how to obtain information on these properties. At the heart we will analyse the dispersion relation of Bloch periodic eigenmodes in MMs and describe how to deduce an effective refractive index. This index will be compared with an index as retrieved from the reflected and transmitted amplitude of a plane wave at a finite MM slab. The analysis is done as a function of the frequency, the angle of incidence, and the polarization. Although both indices are in excellent agreement, we will argue that such an index ceases to have a meaning as a material but has to be understood as a wave parameter only. Such an index is only of use to describe the light propagation through the MM in a simplified manner. We will quantify properties in MMs such as anisotropy, and spatial and temporal dispersion.