# HL 54: Photonic Crystals: Theory

Time: Thursday 14:00–15:45 Location: H13

HL 54.1 Thu 14:00 H13

**Thermal emission from finite photonic crystals** — •Kurt Busch[1], Christian Schuler[1], Christian Wolff[1], and Marian Florescu[2] — [1]Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology, 76128 Karlsruhe, Germany — [2]Department of Physics, Princeton University, Princeton, NJ 08544, U.S.A.

We present a microscopic theory of thermal emission from truncated photonic crystals and show that the relevant physical parameters such as the directional spectral emissivity can be obtained from standard photonic bandstructure computations without any approximation. This allows us to identify the physical mechanisms how interfaces modify the potentially super-Planckian radiation flow inside infinite photonic crystals [1] such that thermal emission from truncated systems remains consistent with the fundamental limits set by Planck's law [2]. As an application, we further demonstrate how a judicious choice of a surface termination facilitates considerable control over both the spectral and angular thermal emission properties [2,3].

[1] M. Florescu et al., Phys. Rev. B **75**, 201101(R) (2007).
[2] C.J. Schuler et al., Appl. Phys. Lett., in press.
[3] C.J. Schuler et al., submitted.

HL 54.2 Thu 14:15 H13

**Simulations of Liquid Crystal Infiltrated Photonic Crystal Fibers Using the Fourier Modal Method** — •Thomas Zebrowski, Sabine Essig, and Kurt Busch — Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures (CFN), Karlsruher Institut für Technologie (KIT), 76128 Karlsruhe, Germany

Liquid crystal infiltrated photonic crystal fibers are challenging systems for an accurate simulation because of their characteristic tiny features in the transverse plane coupled with a huge aspect ratio in propagation direction. In this contribution we demonstrate that the Fourier Modal Method is applicable to treat such problems. First, we extend the method to handle anisotropic materials and fully exploit the system symmetries which leads to significantly reduced demand for computational resources. This allows to make maximum use of the method's advantages which come via a scattering matrix algorithm that handles the typically slow or periodic structural variations along the propagation direction.

HL 54.3 Thu 14:30 H13

**Transport Theory of Diffusive Random Lasers** — •Regine Frank[1,2], Andreas Lubatsch[1], and Johann Kroha[1] — [1]Physikalisches Institut, Universität Bonn, 53115 Bonn, Germany — [2]Present address: KIT Karlsruhe, Germany

Despite substantial investigations mostly for low dimensional systems, the physics of homogeneously disordered random lasers bears intriguing, open problems. The conditions for transport and localization and, in particular, the origin of confined spacial regions from which laser radiation is emitted ("lasing spots") as well as the dependence of their size on the pump rate, have remained poorly understood. We present a semi-analytic transport theory for light propagating diffusively, in a random, lasing medium, including self-interference ("Cooperon") corrections [1]. The diffusion coefficient is strongly renormalized by the non-linear gain rate. The latter is obtained from the local laser rate equations which, in turn, are controlled by loss channels due to diffusion and surface losses. In the stationary lasing state, the volume gain is compensated by surface losses. We solve the resulting surface boundary condition problem to obtain an analytical equation for the average lasing spot size. The full spatial intensity profile of lasing spots is obtained numerically in dependence of the pump rate. We show that the lasing spot size is closely related to the requirement of causality within a coherent lasing mode. The results are in qualitative agreement with experimental findings.

[1] R. Frank. A. Lubatsch, J. Kroha, J. Optics A **11**, 114012 (2009).

HL 54.4 Thu 14:45 H13

**Light Propagation in Anisotropic Disordered Media, Transverse Diffusion** — •Andreas Lubatsch[1] and Regine Frank[2] — [1]Physikalisches Institut, Universitaet Bonn, 53115 Bonn, Germany — [2]Institut fuer Theoretische Festkoerperphysik, Universitaet Karlsruhe, 76128 Karlsruhe, Germnany

We present a semi-analytical theory for light propagation in three dimensional, strongly scattering, anisotropic , disordered dielectrics. The anisotropy of the system is incorporated by a tensor dielectric function. By starting at Maxwell's equations, we derive a general transport theory for ligh including transport quantities such as energy transport velocity, transport mean free path and diffusion coefficient. This approach is based on a fully vectorial treatment of the generalized kinetic equation and also incorporates a generalized Ward identity for these systems. Furthermore, self-interference contribution to the transport are included by means of a generalized localization theory based on a cooperon resummation first derived for electrons by Vollhardt and Wölfle. Numerical evaluations including transverse diffusion in presence of magnetic fields are discussed.

HL 54.5 Thu 15:00 H13

**Diagrammatic Theory of Anderson Localization of Light in Random Photonic Crystals Including Polarization** — Zhong Yuan Lai, •Andreas Lubatsch, and Johann Kroha — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115, Bonn

Anderson localization of light (ALL) is of interest both for fundamental reasons, because it is not disturbed by interaction effects, and for applications, e.g. in random lasers. However, the realization of ALL has been hampered by weak scattering amplitudes as well as by the reduced interference due to the polarization degree of freedom.

We develop a realistic description of diffusion and localization of light in random photonic crystals, where ALL is expected to be enhanced near a photonic band gap. Starting from a Wannier representation, we develop a tight-binding model of the disordered photonic crystal. The transverse vector nature of light implies the existence of two modes per site in the relevant energy band. They are coupled due to the disorder. The resulting pseudospinor theory is analytically tractable with strongly reduced effort compared to a plane-wave expansion [1]. We generalize the existing, selfconsistent theory of Anderson localization of classical waves [2] to include polarization. The transport velocity and the diffusion coefficient are calculated including a selfconsistent resummation of backscattering ("Cooperon") diagrams.

We find important corrections to the scalar theory due to different disperions of the two polarization modes and due to absorption in the medium.

HL 54.6 Thu 15:15 H13

**Simulation model of 2D metallic photonic quasicrystals** — •Christina Bauer, Georg Kobiela, and Harald Giessen — 4th Physics Institute, University of Stuttgart, 70550 Stuttgart, Germany

We are going to present a step-by-step model to predict the optical properties of 2D metallic photonic quasicrystals. For this model a 2D Fourier transform of the spatial arrangement of the nanoparticles in combination with polarization properties and dispersion relations is used. In the final step the line shape of such structures is considered. We manufactured a number of these structures and verified our model which yields very good quantitative agreement. This model can also be extended for angle-dependent incidence of the light, which we confirmed experimentally as well. We verify our results also for 2D rectangular lattices. Our findings are important for plasmonics in quasicrystal arrangements in general, for example in nanohole arrays [1, 2, 3].

[1] T. Matsui et al., Nature 446, 517 (2007).
[2] C. Rockstuhl et al., Appl. Phys. Lett. 91, 151109 (2007).
[3] N. Papasimakis et al., Appl. Phys. Lett. 91, 081503 (2007).

HL 54.7 Thu 15:30 H13

**Resonant mode approximation for deriving optical properties of nanostructured materials** — •Thomas Weiss[1,2], Nikolay Gippius[2,3], Sergei Tikhodeev[3], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Germany — [2]LASMEA, University Blaise Pascal, France — [3]General Pyhsics Institute, Russian Academy of Science, Russia

A lot of attention has been paid in the last years to the optical properties of nanostructured materials such as photonic crystals, metamaterials, and nanoantennas. The numerical calculation of these properties is often very time-consuming and, hence, simple models are desired for a fast approximation of the spectral behavior. We are going to present the resonant mode approximation, where the spectra can be derived from the calculation of the resonant mode. As a starting point, we use the scattering matrix approach for stacked periodic structures to obtain the resonant field distribution as well as the resonance position in the complex frequency plane. Then, we can approximate the scattering matrix for frequencies close to the resonance without any fitting procedures for describing the response of the structure on plane wave incidence. Several examples will be shown to elucidate the versatility of the method.