DS 36: Plasmonics and Nanophotonics HL-I (jointly with HL and O)

Time: Wednesday 10:15–12:15 Location: POT 251

DS 36.1 Wed 10:15 POT 251

Optical Gain in Rolled-up Semiconductor/Metal Metamaterials — Stephan Schwaiger, Markus Broell, Ricardo Costa, Matthias Klingbeil, Aune Koitmae, Wolfgang Hansen, Detlef Heitmann, and •Stefan Mendach — Institute for Applied Physics, University of Hamburg, Jungiusstrasse 11, 20355 Hamburg, Germany

Stimulated emission from optically active gain material is one of the most promising ways to solve the problem of losses in metamaterials [1, 2]. Here, we present gain measurements on rolled-up semiconductor/metal hybrid metamaterials [3] containing InGaAs quantum wells. We find a characteristic increase and decrease of the transmission through the metamaterial when optically pumping the quantum well. We observe positive gain of up to 15% at the high energy tails of the photoluminescence peaks of the quantum well and negative gain of similar magnitude at the low energy tails. This behaviour can be well reproduced with transfer matrix calculations which model each peak in the quantum well photoluminescence by a Lorentz oscillator.

[1] Y. Sivan, S. Xiao, U. K. Chettiar, A.V. Kildishev, and V. M. Shalaev, Opt. Exp. 26, 24060 (2009). [2] S. Xiao, V. P. Drachev, A.V. Kildishev, X. Ni, U. K. Chettiar, H.-K. Yuan, and V.M. Shalaev, Nature 466, 735 (2010). [3] S. Schwaiger, M. Bröll, A. Krohn, A. Stemmann, C. Heyn, Y. Stark, D. Stickler, D. Heitmann, and S. Mendach, Physical Review Letters 102, 163903 (2009)

DS 36.2 Wed 10:30 POT 251

Calculation of Transmission through rolled-up three dimensional Metamaterials — •Andreas Rottler, Stephan Schwaiger, Aune Koitmäe, Matthias Klingbeil, Markus Bröll, Detlef Heitmann, and Stefan Mendach — Institute of Applied Physics, University of Hamburg, Germany

Metamaterials are artificial structures where permittivity and permeability can be designed on demand and may exhibit values which are not observed in nature. In this talk, we present finite-difference time-domain simulation results on a metamaterial which consists of curved alternating layers of metal/semiconductor films. Such structures can be prepared from self-rolling strained metal/semiconductor layers and exhibit an anisotropic permittivity with tunable plasma frequency allowing for hyperlensing in the visible [1]. We performed simulations where we varied the parameters of the structure in order to optimize the transmission through the curved metamaterial.

We gratefully acknowledge support by the DFG via the Graduiertenkolleg 1286.

[1] S. Schwaiger et al., Phys. Rev. Lett. 102, 163903 (2009)

DS 36.3 Wed 10:45 POT 251

Auxiliary basis functions for the Wannier function based 2D TE photonic crystal circuit design — •Patrick Mack, Christian Wolff, and Kurt Busch — Institut für Theoretische Festkörperphysik (TFP) and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), 76128 Karlsruhe, Germany

Photonic crystals are periodic dielectric heterostructures exhibiting a band structure for light. Adjusting fabricational parameters offers the possibility to open complete, photonic band gaps prohibiting light propagation regardless of direction. Purposely designed defect structures introduce localized light modes in these forbidden frequency ranges, creating resonator modes, waveguides and functional elements for photonic devices, whose design optimization has to be carried out numerically.

The Wannier function (WF) approach yields a tight-binding like numerical method which expands these localized states in a set of localized basis functions and proved to be particularly efficient for E-polarized (TM) light in the combination with an S-matrix approach. In the H-polarized (TE) case, however, slow convergence limited the applicability of this Ansatz. We propose to use additional auxiliary basis functions, that improve convergence and are capable of modeling 2D TE large scale photonic circuitry (typically air holes in silicon) involving non-etched holes and tunable linear anisotropic media, such as liquid crystals and magneto-optic materials.

DS 36.4 Wed 11:00 POT 251

Coupling model for the derivation of optical resonances in stacked nanogratings — •Thomas Weiss[1,2], Nikolay A. Gippius[2,3], Sergei G. Tikhodeev[3], Gérard Granet[2], Liwei Fu[1], Richard Taubert[1], and Harald Giessen[1] — [1]4th Physics Institute and Research Center Scope, University of Stuttgart, Stuttgart, Germany — [2]LASEMA, University Blaise Pascal, Aubière, France — [3]A. M. Prokhorov General Physics Institute, Russian Academy of Sciences, Moscow, Russia

Nanogratings have become one of the most important structures in modern nanooptics over the last few years. They can be used in different fields such as photonic crystals and metamaterials. However, the experimental fabrication as well as the corresponding numerical calculation is usually very time-consuming. Hence, simple models are required for a qualitative derivation of the optical behavior of such structures. Here, we present a method to approximate the optical resonances of stacked nanogratings using the Fourier modal method and optical scattering matrix theory. The resulting equations form a low-dimensional linear eigenvalue problem that can easily be solved for varying grating distances, including near field effects as well as multiple scattering in the far field regime with strong coupling to Fabry-Perot resonances. The method is not only accurate and fast; it provides also additional physical insight, as the individual components of the coupling mechanism can be studied independently. Furthermore, the model involves no fitting parameters. All quantities can be derived ab initio by the scattering matrix formalism.

DS 36.5 Wed 11:15 POT 251

3D photonic crystal integrated in a mircomorph thin film silicon tandem cell — •Johannes Üpping[1], Thomas Beckers[2], Reinhard Carius[2], Uwe Rau[2], Stephan Fahr[3], Carsten Rockstuhl[3], Falk Lederer[3], Matthias Kroll[4], Thomas Pertsch[4], Lorenz Steidl[5], Rudolf Zentel[5], and Ralf B. Wehrspohn[1] — [1]Institute of Physics, mikroMD, University of Halle Wittenberg — [2]Institute of Energy Research, IEF-5 Photovoltaics, Forschungszentrum Jülich GmbH — [3]Institute of Condensed Matter Theory and Sold State Optics, Friedrich-Schiller-Universität Jena — [4]Institute of Applied Physics, Friedrich-Schiller-Universität Jena — [5]Institute of Organic Chemistry, Johannes Gutenberg-Universität Mainz

A 3D photonic intermediate reflector for textured micromorph silicon tandem solar cells has been investigated. In thin-film silicon tandem solar cells consisting of amorphous and microcrystalline silicon with two junctions of a-Si/μc-Si, efficiency enhancements can be achieved by increasing the current density in the a-Si top cell. It is one goal to provide an optimized current matching at high current densities. For an ideal photon-management between top and bottom cell, a spectrally selective intermediate reflective layer (IRL) is necessary. We we present the first fully integrated 3D photonic thin-film IRL device incorporated in a state-of-the-art textured tandem solar cell. The design, the preparation and numerical calculations of a 3D self organized inverted opal photonic crystal structure in a textured micromorph tandem solar cell are presented.

DS 36.6 Wed 11:30 POT 251

Angle-resolved fluorescence spectroscopy in photonic crystals — •Rebecca Wagner, Lars Heerklotz, and Frank Cichos — Molecular Nanophotonics, University of Leipzig, Germany

Photonic Crystals (PCs) are materials with periodically varying dielectric constant. Multiple scattering of light on this spatially modulated refractive index leads to the formation of a photonic band structure including photonic band gaps. The optical density of states is redistributed as compared to a homogeneous material and is described by the fractional local density of states (FLDoS). This leads to a modified propagation of light in the material.

The spectral and angular position of the band gaps can, for example, be probed by reflection spectroscopy. Since reflections can occur on different lattice plane families, the detection angle has to be varied for every angle of incidence, making this method very time consuming. Further, an average of the reflectivity over differently oriented crystal domains is taken.

We develop a method to overcome these problems using fluorescence spectroscopy of single internal emitters. By applying a special technique we are able to measure angle resolved fluorescence spectra for many emission angles at the same time. Comparison of these spectra to spectra of emitters outside the PC gives the FLDoS, which also contains information about the symmetry of the emitter's local environment. By varying emitters and lattice constants of the PC, different regions of the band structure can be probed.

DS 36.7 Wed 11:45 POT 251

The Concepts of Self-assembled 3D Photonic Crystals for High Temperature IR reflective coatings — •Hooi Sing Lee[1], Alexander Petrov[1], Manfred Eich[1], Roman Kubrin[2], Gerold Scheider[2], Julien Bachmann[3], and Kornelius Nielsch[3] — [1]Institut für Optische und Elektronische Materialien, TUHH, Hamburg, Deutschaland — [2]Institut für keramische Hochleistungswerkstoffe , TUHH, Hamburg, Deutschaland — [3]nstitut für Angewandte Physik, Uni Hamburg, Hamburg, Deutschaland

The study is undertaken to develope a self-assembled 3D microporous structure which is based solely on low thermal conductivity ceramic materials and is capable of reflecting IR radiation at any incident angle over a wide spectral range.The practical applications which will benefite most from this study are ceramic thermal barrier coatings (TBC) and selective filters for thermophotovoltaics (TPV). Finite Integration Technique (FIT) simulations have shown that yttria stabilized zirconia (YSZ) inverse opal with the pore size of $>$ 500nm possesses stopgap in the IR regime and can be tailored to reflect target range of wavelength by changing the lattice constants. The width of the stopgap can be effectively enlarged by stacking several inverse opal with different pore sizes in the subsequent layers and it was shown in simulation and experiment. It was estimated that 9 stacks of such structures can achieved 91% of total hemispherical reflectance in the wavelegth range of 1-6 *m, where the major blackbody radiant power at 1500 K tends to be concentrated. The optical properties of direct opal and inverse opal were measured and compared with the simulations.

DS 36.8 Wed 12:00 POT 251

Bio-inspired multifunctional photonic systems — •Mathias Kolle[1], Peter Vukusic[2], and Joanna Aizenberg[1] — [1]School of Engineering and Applied Sciences, Harvard University, 9 Oxford St, Cambridge, MA-02138, US — [2]School of Physics, Stocker Road, Exeter, EX4 4QL

Biomimetic and bio-inspired attempts to produce novel photonic structures have attracted increasing research interest in recent years. Nature offers an enormous amount of multifunctional micro- and nanostructures that provide outstanding, distinctive, dynamic and tailored coloration and high reflectivity. Various intriguing photonic structures have been identified on the wing scales of beetles, butterflies, the feathers of birds or in marine animals. Nature offers a huge reservoir of blueprints for novel artificial optical materials and photonic structures. We present the development of bio-inspired, dynamic, micro-optical elements that are comparable to some of natures efficient optical systems. Artificially controlled self-assembly combined with established nanofabrication techniques can be used for the development of new optically-adaptive devices. Novel optical elements have to address the aspect of tunability and multifunctionality to be versatile for a wide range of applications. Furthermore, we propose a technique to create fully organic adaptive optical systems based on elastic multilayer micro-rolls.