HL 51: Photonic crystals II

Time: Friday 10:15–12:45 Location: BEY 154

HL 51.1 Fri 10:15 BEY 154

Thermal emission properties of 2D and 3D silicon photonic crystals — •Benjamin Gesemann, Stefan Schweizer, and Ralf B. Wehrspohn — Martin Luther Universität Halle-Wittenberg

We present measurements of the thermal emission properties of electrochemically etched 2D and 3D silicon photonic crystals heated resistively with and without substrate. The Out-of-plane emission properties were recorded and compared to numerical simulation.

HL 51.2 Fri 10:30 BEY 154

Efficient Calculation of the Optical Properties of Stacked Metamaterials in a Fourier Modal Approach — •Thomas Weiss[1,2], Nikolay Gippius[2,3], Sergei Tikhodeev[3], and Harald Giessen[1] — [1]4th Physics Institute, Stuttgart, Germany — [2]LASMEA, Clermont-Ferrand, France — [3]General Physics Institute, Moscow, Russia

Metallic photonic crystals and metamaterials provide features such as band gaps, negative refractive indices, chirality, and polarization effects that can lead to a number of applications. Nowadays, the theoretical description of these structures is based on simple models as well as numerical methods such as FDTD (finite difference time domain) and FMM (Fourier-modal method).

We are going to present efficient techniques such as adaptive spatial resolution [1] and factorization rules [2] to overcome the restrictions in a Fourier-modal S-matrix (scattering matrix) approach [3] caused by the jump discontinuities in the permittivity function. Thus, we can calculate the spectra, eigenmodes, and near-field distributions of two- and three-dimensional metallic photonic crystals and metamaterials with a high accuracy. In addition, we will show that the scattering matrix provides an easy way to derive ellipticity and Stokes parameters. This allows us to study the polarization effects of stacked and rotated structures such as split ring resonators.

[1] G. Granet, J. Opt. Soc. Am. A 16, 2510 (1999).
[2] L. Li, J. Opt. Soc. Am. A 13, 1870 (1996).
[3] D. M. Whittaker and I. S. Culshaw, Phys. Rev. B 60, 2610 (1999).

HL 51.3 Fri 10:45 BEY 154

Tailoring the second-order nonlinear optical properties of silicon by application of inhomogeneous strain — •Clemens Schriever, Daniel Pergande, and Ralf B. Wehrspohn — Institut für Physik, Universität Halle-Wittenberg, Halle, Germany

Silicon has become a promising candidate for integrated optics mainly due to its highly optimized CMOS processing technology and its suitable optical properties at telecommunication wavelengths. The difficulty of integrating silicon into active optoelectronics, where electrical and optical functionalities are combined in a monolithic device, is due to its limited active optical properties. Because of the materials centrosymmetric lattice structure silicon does not exhibit a second-order nonlinear susceptibility and is therefore not suitable for higher-order non-linear optical processes. One possibility to overcome this limitation is to break the centrosymmetry of the atomic lattice. We present first numerical studies and analytical approximations on how inhomogeneous strain can be used to create non-linear optical properties. The variation of magnitude and direction of the applied strain using realistic values of e.g. highly strained SiN-layers allows tailoring the nonlinear optical properties of a silicon photonic device.

HL 51.4 Fri 11:00 BEY 154

Photonic crystal cavities with embedded site-controlled quantum dots — •Martin Kamp, Thomas Sünner, Benedikt Friess, Christian Schneider, Micha Strauss, Alexander Huggenberger, Daniel Wiener, Sven Höfling, and Alfred Forchel — Technisch Physik, Am Hubland, 97074 Würzburg

Photonic crystal (PhC) cavities with embedded quantum dots (QDs) have become an attractive model system for the study of cavity quantum electrodynamics (CQED). In order to maximize the coupling between the cavity and a quantum dot, the emission of the latter has to match the resonance wavelength of the cavity. Furthermore, the dot should be located at the maximum of the localized optical mode. We present a scalable method that allows the fabrication of site-controlled quantum dots embedded in photonic crystal cavities, thus addressing this issue of spatial alignment. First, a set of markers is defined on a GaAs sample, followed by patterning of an array of nano-holes which serve as nucleating centers for the growth of InGaAs QDs. After the epitaxy, membranes with PhC cavities are fabricated. The array of nano-holes and the cavities are both aligned to the markers, resulting in an overlay accuracy of better than 50 nm. Charaterization of the structures was performed by low temperature photoluminescence. The spectra show sharp emission lines, which can be attribued to individual quantum dots and the cavity. An enhancement of the spontaneous emission was observed when the dot was brought in resonance with the cavity by temperature tuning.

HL 51.5 Fri 11:15 BEY 154

Hydrogensensor based on a metallic photonic crystal — •Cornelius Grossmann, Todd P. Meyrath, and Harald Giessen — 4. Physics Institute, University of Stuttgart, Germany

Hydrogen has gained substantial amount of interest in recent years and it is considered to be a future carrier of energy. However, hydrogen can mix and ignite with air in a wide concentration range and surveillance is necessary.

Here, we present an optical hydrogen sensor based on a metallic photonic crystal. Our sample consists of a WO3 waveguide layer and metallic nanowires on top. The nanostructuring is done with interference lithography. Due to incorporation of atomic hydrogen into the crystal lattice structure of WO3, the optical properties of the waveguide-plasmon polariton resonance change in presence of hydrogen. The sharpness of the plasmonic resonance increases the accuracy of our sensor significantly in comparison to a bare WO3 layer.

We present the detection mechanism as well as temperature- and time-dependent measurement results. Advantages and disadvantages over the conventional hydrogen sensors are pointed out and the development towards an all-optical hydrogen sensor with full seperation of detection electronics and measurment optics will be shown as well.

15 min. break

HL 51.6 Fri 11:45 BEY 154

Nonlinear Optical Spectroscopy of Metamaterials — •Mathieu Gentile[1], Mario Hentschel[1], Hongcang Guo[2], Harald Giessen[2], and Manfred Fiebig[1] — [1]Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn, Germany — [2]4. Physikalisches Institut, Universität Stuttgart, Germany

Optical metamaterials recently gained considerable attention since they offer genuinely new optical properties with possible negative value for effective electric permittivity, ε, and magnetic permeability, μ.

We measure the first-ever second harmonic generation (SHG) spectra of ⊔-shaped gold structure arrays on a glass substrate. Using a 130 fs OPA-tunable laser source the spectral response was measured in the SHG range from 1.64 eV to 3.00 eV.

Measurements are in perfect agreement with tensor components allowed by sample symmetry. The linear reflection spectrum of these structures displays a resonance for photon energies around 0.83 eV. In contrast, SHG spectra reveal resonances at different photon energies that are determined by the actual geometry of the metamaterial “atoms” while the linear optical properties of the metamaterial and the spectral characteristics of the gold are of minor significance.

HL 51.7 Fri 12:00 BEY 154

Reversed GaAs pyramids as new optical micro-cavities based on total internal reflection — •Daniel Rülke[1], Matthias Karl[1], Dongzhi Hu[1], Daniel M. Schaadt[1], Benjamin Kettner[2], Sven Burger[2], Frank Schmidt[2], Heinz Kalt[1], and Michael Hetterich[1] — [1]Institut für Angewandte Physik and DFG Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]Zuse Institut Berlin (ZIB), 14195 Berlin, Germany

We investigate the potential of GaAs pyramids standing upside down as a new type of optical micro-cavity based on total internal reflection. The latter are fabricated from molecular-beam epitaxy grown structures utilizing a combination of electron-beam lithography and wet-chemical etching, taking advantage of an AlAs sacrificial layer. Among other things, this approach allows us to realize coupled reversed pyramids or their electrical contacting via small bridges. In the pyramids we place In(Ga)As quantum dot layers as internal light source which emit in the range from 900 to 1050 nm after laser excitation. We identify optical modes in the cavities by their thermal behavior and map their spatial distribution for a better characterization. Due to their easily tunable geometrical dimensions reversed pyramidal resonators can access the intermediate regime between conventional and whispering-gallery-like mode behavior. Therefore, they should be promising candidates to enhance light matter interaction.

HL 51.8 Fri 12:15 BEY 154

Local Infiltration of Individual Pores with Dyes in Macroporous Silicon Photonic Crystals — •Peter W. Nolte[1], Stefan L. Schweizer[1], Daniel Pergande[1], Ralf B. Wehrspohn[1,3], Markus Geuss[2], Martin Steinhart[2], and Roland Salzer[3] — [1]Institut für Physik, Universität Halle-Wittenberg, Halle, Germany — [2]Max-Planck-Institut für Mikrostrukturphysik, Halle, Germany — [3]Fraunhofer-Institut für Werkstoffmechanik, Halle, Germany

Photonic crystals (PhC) are promising candidates for novel optical components. Passive devices realized with PhC, e.g. complex waveguides, are widely known. However, for many applications active devices are required. One possible way to realize such devices is the functionalization of 2D PhC. This can be done by combining 2D PhC with dyes. We present an experimental technique for the infiltration of individual pores which allows the realization of a broad spectrum of different device designs. For the infiltration of individual pores we use 2D PhC templates made of macroporous silicon, electron beam physical vapor deposition, focused ion beam technique, electrochemical deposition and the wetting assisted templating (WASTE)-process.

HL 51.9 Fri 12:30 BEY 154

Thermal Emission in Photonic Crystals — •Christian Schuler[1], Marian Florescu[2], Christian Wolff[1,3,4], Sabine Essig[1,3,4], Thomas Zebrowski[1,4], and Kurt Busch[1,3,4] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]Department of Physics, Princeton University — [3]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe — [4]Karlsruhe School of Optics & Photonics (KSOP), Universität Karlsruhe

Photonic crystals (PCs) exhibit great potential for technological applications that are based on the conversion from energy to light, for example energy-efficient light sources or improved devices for thermophotovoltaics. We analyze the spectral and angular dependence of the thermal radiation emitted from a semi-infinite two-dimensional PC into free space. The emitted light originates from thermally excited Bloch modes, which are obtained from the PC's complex bandstructure. The Bloch modes are coupled to the free space plane waves by a scattering matrix approach. Our results are in good agreement with Kirchhoff's law of thermal radiation and obey the black body limit.