HL 43: Photonic crystals I

Time: Thursday 9:30–12:30 Location: POT 151

HL 43.1 Thu 9:30 POT 151

Electro-optical modulator in a polymer- infiltrated silicon slotted photonic crystal waveguide heterostructure resonator — •Jan Hendrik Wülbern, Alexander Petrov, and Manfred Eich — Institut für Optische und Elektronische Materialen, Technische Universität Hamburg-Harburg, 21073 Hamburg

We present a novel concept of a compact, ultra fast electro-optic modulator, based on photonic crystal resonator structures that can be realized in two dimensional photonic crystal slabs of silicon as core material employing a nonlinear optical polymer as infiltration and cladding material. The novel concept is to combine a photonic crystal heterostructure cavity with a slotted defect waveguide. The photonic crystal lattice can be used as a distributed electrode for the application of a modulation signal. An electrical contact is hence provided while the optical wave is kept isolated from the lossy metal electrodes. Thereby, well known disadvantages of segmented electrode designs such as excessive scattering are avoided. The optical field enhancement in the slotted region increases the nonlinear interaction with an external electric field resulting in an envisaged switching voltage of less than 1 V at modulation speeds up to 100 GHz.

HL 43.2 Thu 9:45 POT 151

Room Temperature Tuning of Photonic Crystal Cavities — •Karoline A. Piegdon[1,2], Heiner Matthias[3], Heinrich-S. Kitzerow[3], Dirk Reuter[4], and Cedrik Meier[2] — [1]University of Duisburg-Essen, Physics Department — [2]University of Paderborn, Nanophotonics and Nanomaterials — [3]University of Paderborn, Physical Chemistry — [4]Ruhr University of Bochum

Photonic crystal (PC) cavities are in the focus of interest due to the strong light-matter interaction, that makes them suitable for quantum electrodynamics in cavities containing semiconductor quantum dots (QDs). Recent experiments with single QDs coupled to a high quality factor cavity mode got most attention, since they show strong cavity-QED effects. However, the inability to fabricate cavities with a designated resonant wavelength makes their tuning indispensable.

In our room temperature photonic crystal cavities we implemented different techniques for reversible or permanent tuning of the resonant mode. We fabricated photonic crystal membranes from a (Al,Ga)As heterostructure; the membrane slab contains self-assembled InAs QDs exhibiting luminescence at 300K between 1000nm and 1300nm. In all experiments we employed control of the refractive index of the surrounding of the photonic crystals in order to gain control over the resonant mode wavelength. Depending on the application, reversible or irreversibel tuning is desired. This is achieved by deposition of thin layers of material on the PC or by using the tunability of liquid crystals.

HL 43.3 Thu 10:00 POT 151

Multiple Scattering of Light in Three-dimensional Photonic Quasicrystals — •Alexandra Ledermann[1], Michael Kallenberg[1], Diederik S. Wiersma[2], Martin Wegener[1], and Georg von Freymann[1] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe, DFG-Center for Functional Nanostructures (CFN) and Institut für Angewandte Physik, Universität Karlsruhe (TH) — [2]European Laboratory for Nonlinear Spectroscopy (LENS) and INFM, Firenze

Quasicrystals (QC) represent a class of solids which lack translational symmetry, yet exhibit perfect long-range order and high-degree rotational symmetries, not necessarily consistent with periodicity. Using direct laser writing [1] we fabricate three-dimensional SU-8 photonic QCs of high quality [2] and study their optical properties. The results of our Laue diffraction experiments and our time-resolved pulse propagation studies are reproduced by our simulations [3], showing that multiple scattering of light plays an important role in describing the unusual properties of QCs. We find features of both, disordered optical systems as well as periodic photonic crystals.

[1] M. Deubel et al., Nature Materials, 3, 444 (2004).
[2] A. Ledermann et al., Nature Materials, 5, 942 (2006).
[3] A. Ledermann et al., Optics Express, submitted (2008).

HL 43.4 Thu 10:15 POT 151

Stereometamaterials — Na Liu[1], •Hui Liu[2], Shining Zhu[2], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, 70569 Stuttgart, Germany — [2]Department of Physics, Nanjing University, Nanjing 210093, P. R. China

Abstract: We introduce a novel concept to nano-photonics, namely stereometamaterials. As model system of stereometamaterials, we theoretically and experimentally study meta-dimers, which consist of a stack of two identical split-ring resonators[1] in each unit cell with various twist angles. We demonstrate that the interplay between electric and magnetic interactions plays a crucial role for the optical properties[2]. Specifically, the influence of higher-order electric multipoles becomes clearly evident. The twisting of stereometamaterials paves the road towards engineering of complex plasmonic nanostructures with tailored electric and magnetic interactions.

[1] N. Liu et al., *Three-dimensional photonic metamaterials at optical frequencies*. Nature Mater. 7, 31 (2008). [2] H. Liu et al., *Magnetic plasmon hybridization and optical activity at optical frequencies in metallic nanostructures.*Phys. Rev. B. 76, 073101 (2007).

15 min. break

HL 43.5 Thu 10:45 POT 151

3D Vectorial Wannier Functions for the Design of Functional Defect Structures in Photonic Crystals — •Chrisitan Wolff[1,2,4], Christopher Kölper[1], Patrick Mack[1,3], Daniel Hermann[1,2], and Kurt Busch[1,2,3,4] — [1]Institut für theoretische Festkörperphysik, Universität Karlsruhe — [2]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe — [3]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft — [4]Karlsruhe School of Optics and Photonics (KSOP), Universität Karlsruhe

Photonic circuits formed by defect arrays in photonic crystals are a promising approach for integrated optics applications. However, such systems combine large spatial extents and highly structured, very regular geometries. As a consequence, conventional numerical methods are challenged by excessive resource consumption. In contrast, the Wannier functions of the unperturbed photonic crystal offer an efficient expansion basis which had been verified in the past for 2D systems, in which the decoupling of the polarizations leads to a scalar problem. We report on the generalization of the method towards fully vectorial 3D photonic Wannier functions and their application to defect structures in 3D photonic crystals and photonic crystal slabs.

HL 43.6 Thu 11:00 POT 151

Silicon-based low-loss photonic crystal waveguides — •Daniel Pergande[1] and Ralf B. Wehrspohn[1,2] — [1]Institut of Physics, Martin-Luther-University Halle-Wittenberg, 06099 Halle — [2]Fraunhofer Institute for Mechanics of Materials, 06120 Halle

Silicon is the dominating material in today's microelectronics, especially in modern telecommunications, and therefore a lot of experience in microstructuring of silicon exists. Its high dielectric constant makes it a promising candidate for PhC fabrication. Furthermore, the possibility of integrating electronics and optics on one chip is of great advantage for silicon-based PhC devices.

We present ridge waveguides and PhC waveguides etched in a high-index-contrast SOI-material made of a thin silicon slab embedded in two silica layers. Hence, fully symmetrical structures can be realized and two important conditions for low-loss guiding of light in PhC waveguides can be matched: First, the high index contrast leads to strong confinement of light, so the PhC waveguides allow theoretically lossless guiding of light because of operating below the lightcone. Second, the symmetry avoids polarization mixing and therefore prevents coupling between guided modes of different polarization.

HL 43.7 Thu 11:15 POT 151

Influence of (Geometrical) Micropillar Properties on the Cavity Quality Factor — •Matthias Karl[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 present numerical studies of optical cavity modes in Bragg micropillars based on a finite element method (FEM). The modes are either obtained by solving an eigenvalue or a scattering problem. Good agreement to experimental data is demonstrated and various influences on the quality (Q) factor of the fundamental pillar mode are investigated.

On the one hand we determine absolute maximum Q factors which depend on the absorption of the semiconductor cavity material. On the other hand geometrical parameters are varied in detail to calculate their influence: Pillar diameter and sidewall inclination show critical features with respect to the Q factor. Furthermore, the top and bottom Bragg stacks are modified in the number of pairs and the etching depth.

15 min. break

HL 43.8 Thu 11:45 POT 151

Polaritonic band gaps in gold films covered with high-refractive index gratings — •Alexander Sprafke, Karl Weis, and Gero von Plessen — 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 polariton dispersions. Here, we experimentally and theoretically investigate the polaritonic band gaps of gold films coated with high-refractive index (n > 2) gratings. The band-gap widths achievable in these structures are studied. In particular, the dependence of the band-gap width on the refractive index and filling factor of the gratings are discussed. We find that the polaritonic band-gap collapses for certain combinations of these parameters. Furthermore, strong variations of the polariton line width as a function of the refractive index and filling factor are predicted.

HL 43.9 Thu 12:00 POT 151

Feature size reduction of silicon inverted direct laser written photonic crystal structures — •Isabelle Staude[1,2], Martin Hermatschweiler[1,3], Georg von Freymann[1,3], and Martin Wegener[1,2,3] — [1]DFG-Centrum für Funktionale Nanostrukturen (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe — [2]Institut für Angewandte Physik, Universität Karlsruhe (TH), 76128 Karlsruhe — [3]Institut für Nanotechnologie, Forschungszentrum Karlsruhe GmbH, 76021 Karlsruhe

Direct laser writing of photonic crystal polymer templates in combination with a subsequent silicon double inversion procedure allows for the fabrication of high quality photonic band gap materials [1]. However, for structures made along these lines, the fundamental band gap has so far been located in the spectral range well above 2 microns wavelength, disqualifying the procedure for applications at telecommunication wavelengths. We could now demonstrate experimentally that feature sizes can be reduced with an improved fabrication scheme. Modifications mainly affect the pre- and post-exposure treatment of the employed photoresist SU-8. The crucial step consists of omitting the standard post-exposure bake relying on optical curing as suggested in [2]. In this manner we have realized silicon woodpile photonic crystal structures with 600 nm lateral rod distance showing prominent photonic stop bands centred around 1.4 microns wavelength, where suppression of transmittance of up to two orders of magnitude is achieved.

[1] N. Tétreault *et al.*, Adv. Mater. **18** (4), 457 (2006)
[2] K. K. Seet *et al.*, Appl. Phys. Lett.. **89** (2), 024106 (2006)

HL 43.10 Thu 12:15 POT 151

Localization limits in slow light photonic crystal waveguides — •Alexander Petrov and Manfred Eich — Technische Universität Hamburg-Harburg, E-12, Eissendorfer Strasse 38, D-21073 Hamburg, Germany

The disorder in photonic crystal waveguides leads to distributed back scattering of guided modes. The backscattering intensity scales with inverse group velocity squared and leads to localization phenomena in slow light waveguides. The use of slow light components above the localization length is not possible due to the phase distortion of the signal. The reflection at a single defect is calculated with eigenmode expansion method and localization lengths are estimated as functions of group velocity in 1D and 2D photonic crystal structures. The effect of absorption and vertical scattering as well as gain on localization phenomena is discussed. It is demonstrated that absorption and vertical scattering effectively diminish localization phenomena and allow use of longer slow light components, whereas gain enhances localization and should be used carefully in slow light structures.