HL 6: Photonic crystals I

Time: Monday 9:30–11:30 Location: EW 201

HL 6.1 Mon 9:30 EW 201

Ultrafast nonlinear switching dynamics in metallic photonic crystals — •Tolga Ergin[1,2], Tilman Höner zu Siederdissen[1,2], Markus Lippitz[1,2], and Harald Giessen[2] — [1]Max-Planck-Institut für Festkörperforschung, 70569 Stuttgart — [2]4. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart

We investigate one-dimensional photonic crystals consisting of periodically arranged alternating layers of a metal and a dielectric. Spectral windows of high transmission in these structures allow the exploitation of the nonlinear transmissive properties of the sample. Recent experiments suggest the possibility of suppressing these windows with a sub-picosecond response and picosecond recovery time by intense pulsed laser pumping. Our research deals with the temporal dynamics as well as intensity and wavelength dependencies of this effect. Understanding these yet unknown issues is essential for maximization of the differential transmission and thus for possible switching applications.

HL 6.2 Mon 9:45 EW 201

Tailoring the polaritonic stop gap in metallo-dielectric photonic crystal superlattices — •Tobias Utikal[1], Thomas Zentgraf[1], André Christ[2], Sergei G. Tikhodeev[3], Nikolai A. Gippius[3], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart, Germany — [2]École Polytechnique Fédérale de Lausanne, Switzerland — [3]General Physics Institute, Moscow, Russia

We experimentally and theoretically investigate the influence of the superlattice parameters on the polaritonic stop gap in metallo-dielectric photonic crystal superlattices. We show that the stop gap can be tailored by structuring the elementary unit cells of the superlattice.

Our model system consists of periodically arranged metal nanowires on top of a dielectric slab waveguide. With normal light incidence, a collective electron oscillation in the wires as well as a photonic mode in the waveguide slab can be excited. These modes form a waveguide plasmon polariton in the strong coupling regime. By tilting the angle of incidence of the light, the in-plane wavevector is changed, hence allowing to measure k-dependent dispersion as well as the size of the stop gap. For our specific superlattice case, we constructed metallic photonic crystal slabs by creating supercells from standard metallic photonic crystal building blocks and varied the superlattice parameters such as cell size and inter-cell distance. The optical properties were studied by conventional angle-resolved white-light transmission measurements.

We were able to explain the experiments using a miniband model and reproduced the results by scattering matrix based calculations.

HL 6.3 Mon 10:00 EW 201

Nonlinear and bistable transmission of high quality factor GaAs photonic crystal cavities — •Martin Garbos, Thomas Sünner, Thomas Schlereth, Sven Höfling, Martin Kamp, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg

Two-dimensional photonic crystal (PhC) cavities can localize light in small modal volumes with high quality factors. This leads to a strong enhancement of the field in the cavities, allowing an observation of nonlinear effects at very low power levels of a few μW. We have studied the nonlinear transmission of PhC cavities based on GaAs membranes. The cavities are realized by small local changes of the geometry (e.g. lattice period or hole diameter) of PhC waveguides. A tunable laser source at $1.55 \mu m$ was used to probe the structures.

The transmission of the cavities has a Lorentzian shape with quality factors of up to 200000 at low power levels. At higher power levels, two photon absorption (TPA) becomes more and more dominant. Most of the generated carriers recombine non-radiatively, leading to an increase of the temperature and the refractice index. The corresponding redshift of the cavity resonance results in an apparent broadening of the cavity transmission when the tunable laser is swept over the resonance. At a detuning of +10 pm from the resonance, a hysteretic behavious was found when the input power was modulated.

HL 6.4 Mon 10:15 EW 201

Gas sensing using photonic crystal cavities — •Thomas Stichel, Thomas Sünner, Thomas Schlereth, Sven Höfling, Soon-Hong Kwon, Martin Kamp, and Alfred Forchel — Technische Physik, Universität Würzburg, Am Hubland, 97074 Würzburg

Cavities in two-dimensional photonic crystals (PhC) can localize light in mode volumes on the order of a cubic wavelength. Due to the high quality factor of the cavities, which can be as high as 10^6, the spectral position of the resonance can be a very sensitive probe for local changes of the refractive index.

We have studied the dependence of the resonance wavelength of PhC cavities on the type and pressure of the ambient gas. The cavities are based on photonic crystals etched into GaAs membranes. A small change of the lattice constant or the width of a W1 PhC waveguide over a few lattice constants is used to provide the optical confinement. The transmission measurements were performed in a box that can be evacuated or filled with different gases. Light from a tunable laser source at $1.55 \mu m$ is used to probe the resonance of the cavities. Measurements of the cavity resonance in different gaseous environments (N_2, SF_6, He) show a a clear dependence of the resonance on the refractive index and the pressure of the gas. Changes of the refractive index on the order of $2 * 10^{-4}$ can be readily detected and are in good agreement with three dimensional finite difference time domain calculations.

HL 6.5 Mon 10:30 EW 201

Coupling of Photonic Resonators with Liquid Crystals — •Karoline A. Piegdon[1], Heiner Matthias[2], Heinz-S. Kitzerow[2], and Cedrik Meier[1] — [1]Experimental Physics, Group NanoPhox, University of Duisburg-Essen — [2]Faculty of Science, Physical Chemistry, University of Paderborn

In order to achieve resonance between a photonic resonator with high quality factor and an emitter with narrow bandwidth, continuous tuning of the resonance frequency is desirable. However, in a semiconductor cavity, it is very difficult to alter the optical path length for this purpose. Matching the frequency of the emitter only by adjusting the device geometry is nearly impossible since even small fabrication imperfections affect the resonance frequency of the cavity considerably. Liquid crystals (LC) are promising candidates to make semiconductor devices tuneable since their refractive indices depend strongly on temperature and external fields.

Here, we report about GaAs microdisks (MD) with InAs quantum dots as built-in light emitters. The MD are embedded in the LC 5CB. The LC was aligned by surface treatment and an electric field. Subsequently, the temperature induced spectral shift of a cavity mode was monitored. The peak wavelength was shifted by 7.5 nm with increasing temperature at the nematic-isotropic phase transition. FDTD simulations and theoretical estimates are in agreement with this shift value. The mode shift was also monitored in situ while the LC was aligned in an electric field. In conclusion, a novel hybrid photonic device is presented that can be tuned by temperature and external fields.

HL 6.6 Mon 10:45 EW 201

Silicon-based low-loss photonic crystal waveguides — •Daniel Pergande[1], Peter Nolte[1], Alexey Milenin[2], and Ralf B. Wehrspohn[1] — [1]Institut of Physics, Martin-Luther-University Halle-Wittenberg, 06099 Halle — [2]Max-Planck-Institute of Microstructure Physics, Weinberg 2, 06120 Halle, Germany

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 (Photonic Crystal) 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: The symmetry avoids polarization mixing and the high index contrast leads to strong confinement of light, so the PhC waveguides allow theoretically lossless guiding of light because of operating completely below the lightcone.

Since the PhC-structures are formed by air pores in the SOI-material, a great degree of freedom consists in the infiltration of the pores. This leads to a new approach for designing PhC-based devices.

HL 6.7 Mon 11:00 EW 201

implementation of adaptive spatial resolution in the scattering matrix approach: towards improvement of convergence for two dimensional photonic crystal slabs — •Thomas Weiss[1], Sergei Tikhodeev[2], and Harald Giessen[1] — [1]4. Physikalisches Institut, Universität Stuttgart, Germany — [2]General Physics Institute, Moscow, Russia

Many attempts have been made to improve the convergence of Fourier modal methods to calculate the optical properties of slabs of 2D-periodic metallic photonic crystals and metamaterials. A key reason for the bad convergence is the discontinuity of the permittivity in patterned structures which results in fictitious localized plasmons on the distortions of the truncated Fourier transformed permittivity.

In numerical simulations with Fourier modal methods we have to truncate the Fourier expansions. If the truncation order is too small then additional resonance-artefacts may occur. Hence it is important to take a sufficient number of modes into account. However, especially for 2D structures we are limited by the operations and memory of computers. Therefore, an adaptive spatial resolution was suggested in order to increase the resolution at the transition between different materials. Hence, higher order modes will be included even if the truncation order is small.

We implemented such a coordinate transformation in the scattering matrix approach (up to now for one-dimensionaly-periodic structures) and are going to present results demonstrating improvement of convergence as well as analytical investigation of the scheme.

HL 6.8 Mon 11:15 EW 201

Optical properties of bowtie slot antennas — •Hongcang Guo[1], Thomas Zentgraf[1], Todd Meyrath[1], Na Liu[1], Liwei Fu[1], Heinz Schweizer[1], Stefan Kaiser[2], and Harald Giessen[1] — [1]4th Physics Institute, University of Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart, Germany — [2]1st Physics Institute, University of Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart, Germany

Optical nanoantennas recently have gained considerable attention[1,2] due to their potential of localizing optical fields on a subwavelength scale. We study the geometrical dependence of the resonant properties of bowtie slot antennas in the optical regime by experiments and numerical simulations. Two types of transmission resonances in the visible and near infrared range are observed for the subwavelength scale antennas. For slot antennas of several ten nanometers thickness, only localized plasmonic resonances are observed and the resonant wavelength shows a linear dependence on the bowtie aperture perimeter. As for several hundred nanometer thick slot antennas, in addition to localized plasmonic resonances, Fabry-Perot-like resonances are excited at the shorter wavelength range, and the resonant wavelength shows a strong dependence on antenna thickness.

[1] P. Mühlschlegel et al., Science 308, 1607 (2005) [2] L. Novotny, Phys. Rev. Lett. 98, 266802 (2007)