Q 35 Poster Photonische Kristalle

Zeit: Dienstag 16:30–18:30 Raum: Labsaal

Q 35.1 Di 16:30 Labsaal

All-optical switching in metallic photonic crystals — •Dietmar Nau[1], Ralph P. Bertram[2], Karsten Buse[2], Thomas Zentgraf[3], Jürgen Kuhl[3], Sergei G. Tikhodeev[4], and Harald Giessen[5] — [1]Institut für Angewandte Physik, Universität Bonn, Wegelerstraße 8, D-53115 Bonn — [2]Physikalisches Institut, Universität Bonn, Wegelerstrasse 8, D-53115 Bonn — [3]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, D-70569 Stuttgart — [4]A. M. Prokhorov General Physics Institute RAS, Moscow 119991, Russia — [5]4. Physikalisches Institut, Universität Stuttgart, Pfaffenwaldring 57, D-70550 Stuttgart

Metallic photonic crystals slabs (MPCS) and photoaddressable polymers (PAP) have attracted a lot of interest recently. Both materials are considered to have the potential to be used in future optical device applications. In this work we combine a MPCS with an additional PAP-layer. We show that the optical properties of this metal-polymer compound system can be reversibly switched all-optically. The optical properties of the system are dominated by the pronounced and steep optical resonances of the MPCS. The large variable birefringence of PAP upon light illumination is used to shift the resonances spectrally. We used a pump-probe experiment to examine the influence of light polarization and exposure on the optical properties [1]. Large spectral shifts of the resonances as well as the reversibility of the switching effect are observed. Comparing the experimental results with scattering-matrix calculations reveals the underlying refractive index changes and allows a quantitative modeling of the compound system.

[1] D. Nau et al., Appl. Phys. B, in press (2006).

Q 35.2 Di 16:30 Labsaal

Director Fields and Optical Properties of Liquid Crystals in Photonic Crystals — •Heinz Kitzerow and Heinrich Matthias — Universität Paderborn, Warburger Str. 100, 33098 Paderborn

It is well known that nematic liquid crystals can be utilized to shift the stop band of a photonic crystal. Research on the director field of liquid crystals filled in macropores is necessary in order to achieve a better understanding of the optical properties of these tunable photonic crystals. Our recent studies on homeotropically aligned liquid crystals show that the modulation of the pore diameter stabilizes periodic arrays of ring disclinations in an escaped radial director field [1]. In this contribution, theoretical examinations of the transmission spectra using both the Berreman 4x4-matrix method and a one dimensional transfer model are presented and compared to experimental results.

[1] H. Matthias, T. Röder, S. Matthias, R. B. Wehrspohn, S. Picken and H.-S. Kitzerow: "Spatially Periodic Liquid Crystal Director Field Appearing in a Photonic Crystal Template", Appl. Phys. Lett. 87, 241105 (2005).

Q 35.3 Di 16:30 Labsaal

Effective mirror model for disordered quasi-1d photonic crystals — •Meikel Frank[1] and Kurt Busch[1,2,3] — [1]Institut für Theoretische Festkörperphysik, Universität Karlsruhe — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft — [3]DFG Forschungszentrum Center for Functional Nanostructures (CFN), Universität Karlsruhe

Based on the S-matrix-method of Lalanne[1] we present a theoretical model describing the propagation and coupling losses in disordered quasi-1d photonic crystals(PCs). This is done by separately studying the in/out-coupling between planar wave guides and semi-infinite PCs. For these systems we create an effective mirror describing the interfaces via reflection, transmission and scattering losses. The model is tested by comparing its predictions with exact numerical calculations of transmission and reflection through ideal finite-sized PCs. Based on that, we extend our study to include the effects of various types of fabrication tolerances. This allows us to investigate how different types of disorder affect the performance of finite-sized PCstructures. Therefore, the study is of particular interest for the development of PC functional elements.

[1] P.Lalanne, J.-P.Hugonin and Q.Cao J.Opt.Soc.Am.A **18** 11 2001

Q 35.4 Di 16:30 Labsaal

Electrooptically Tunable Photonic Crystals — •Jan Hendrik Wülbern[1], Markus Schmidt[1], Manfred Eich[1], Uwe Hübner[2], Richard Boucher[2] und Rudolf Zentel[3] — [1]Technische Universität Hamburg Harburg, Materialien der Elektrotechnik und Optik, Eissendorferstraße 38, 21073 Hamburg — [2]Institut füt Physikalische Hochtechnologie Jena, A. Einstein Str. 9, 07745 Jena — [3]Institut für Organische Chemie, Universität Mainz, Duesbergweg 10 - 14, 55099 Mainz

We report on electrooptical modulation in a photonic crystal slab waveguide resonator which contains a nanostructured second-order-nonlinear optical polymer. The electrooptical susceptibility in the core was induced by high electric-field poling. A square lattice of holes carrying a linedefect was transferred into the slab by electron-beam-lithography and reactive-ion-etching. Applying an external electric modulation voltage to electrodes leads to a linear electrooptical shift of the resonance spectrum based on the electronic displacement polarization in a noncentrosymmetric medium (Pockels-effect). This effect is therefore inherently faster than other electrooptic modulation effects in nanophotonics.

Q 35.5 Di 16:30 Labsaal

Emissionsspektrum eines mit Yb dotierten mikrostrukturierten Faserlasers — •Sergej Wexler[1], Klaus Mörl[2], Klaus Sengstock[1] und Valeri Baev[1] — [1]Institut für Laserphysik, Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg — [2]Institut für Physikalische Hochtechnologie, Albert-Einstein-Straße 9, 07745 Jena

Mikrostrukturierte Fasern erlauben Absorptionsmessungen durch Lichtabsorption der evaneszenten Lichtwelle in Luftkanälen der Faser, die mit dem Probegas gefüllt sind [1]. Die Nachweisempfindlichkeit dieser Messungen ist durch die Länge der Faser bestimmt. Eine substantielle Erhöhung der Empfindlichkeit wird erwartet, wenn sich die mikrostrukturierte Faser innerhalb des Resonators eines Vielmodenlasers befindet [2]. Aus dieser Hinsicht ist die Verwendung von dotierten, mikrostrukturierten Fasern besonders günstig. Wir haben verschiedene dotierte und undotierte mikrostrukturierte Fasern untersucht und festgestellt, dass das Emissionsspektrum eines Vielmodenlasers mit einer mikrostrukturierter Faser durch spektrale Modulation stark ausgeprägt ist. Diese Modulation entspricht mehreren "microbandgaps", die durch Spektralmodulation der transversalen Komponente des Lichtfeldes auftritt. Aus diesem Grund sollte für empfindliche Messungen eine mikrostrukturierte Faser mit "random-hole"-Konfiguration [1] besonderes gut geeignet sein.

[1] G.Pickel, W.Peng, A.Wang, Opt.Lett. 29, 1476 (2004)
[2] V.M.Baev, T.Latz, P.E.Toschek, Appl.Phys. B 69, 171 (1999)

Q 35.6 Di 16:30 Labsaal

Interface Design in Photonic Crystals — •Daniel Hermann[1,2], Sergei Mingaleev[1,2], and Kurt Busch[1,2,3] — [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

We present scattering matrix calculations using localized photonic Wannier functions as optimally adapted basis [1,2] to efficiently characterize interfaces between different photonic functional elements, such as coupled waveguides in two different photonic crystals. The Wannier function S-matrix approach allows us to design the coupling region in such a way that the transmission through these interfaces is optimized over a desired frequency range. Furthermore, the method may also be applied to find efficient coupling designs between slab waveguides and PC line defect waveguides.

[1] J. Phys.: Condens. Matter 15, R1233 (2003)
[2] Opt. Lett. 28, 619 (2003)

Q 35.7 Di 16:30 Labsaal

Microscopic self-consistent analysis of the light-matter coupling in semiconductor photonic-crystal structure — •Torsten Meier[1], Bernhard Pasenow[1], Matthias Reichelt[1,2], Tineke Stroucken[1], Armis R. Zakharian[2], Jerome V. Moloney[2], and Stephan W. Koch[1] — [1]Department of Physics and Material Sciences Center, Philipps University, Renthof 5, D-35032 Marburg — [2]Arizona Center for Mathematical Sciences, University of Arizona, Tucson, AZ 85721, USA

In hybrid systems which consist of semiconductor nanostructures and dielectric photonic crystals significant aspects of the light-matter interaction can be tailored. Such structures are described by a microscopic theory which provides a self-consistent solution of the dynamics of the electromagnetic field and the material excitations. The theory is applied to investigate spatial inhomogeneneities of the optical properties, in particular, excitonic resonances, wave packet dynamics, and the optical gain are analyzed [1,2]. Additionally, the optical properties of quantum wells embedded in one-dimensional photonic crystals are investigated. If such structures are placed inside a microcavity, the gain increases superlinearly with the number of wells [3].

[1] M. Reichelt, B. Pasenow, T. Meier, T. Stroucken, and S.W. Koch, Phys. Rev. B **71**, 035346 (2005).
[2] B. Pasenow, M. Reichelt, T. Stroucken, T. Meier, and S.W. Koch, Phys. Rev. B **71**, 195321 (2005).
[3] B. Pasenow, M. Reichelt, T. Stroucken, T. Meier, S.W. Koch, A.R. Zakharian, and J.V. Moloney, J. Opt. Soc. Am. B **22**, 2039 (2005).

Q 35.8 Di 16:30 Labsaal

Nonlinear time-domain simulations with exponential integrators using Krylov-subspace methods — •Martin Pototschnig[1], Jens Niegemann[1,2], Lasha Tkeshelashvili[3,2], and Kurt Busch[1,3,2] — [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

In recent years, nonlinear optical systems have attracted broad interest. We propose to use exponential-integrators combined with Krylov-subspace methods to solve the corresponding nonlinear time-dependent Maxwell equations as well as coupled optical quantum-mechanical systems, such as the Maxwell-Bloch equations. These techniques are known to be well suited for highly oscillatory and stiff problems and, therefore, we expect fast and accurate simulations. We will present comparisons of the performance and accuracy of our approach relative to commonly used methods, in particular to nonlinear Finite-Difference Time-Domain techniques. In addition, we demonstrate that the method is capable of describing the Non-Markovian radiation dynamics of emitters in finite Photonic Crystals.

Q 35.9 Di 16:30 Labsaal

Numerical Investigation of Magnetic Metamaterials — •Sven Burger, Benjamin Kettner, Lin Zschiedrich, and Frank Schmidt — Zuse Institute Berlin, Takustraße 7, D - 14195 Berlin

Arrays of miniaturized split ring resonators allow to realize systems with a negative effective permeability in the near infrared regime [1,2]. We discuss the use of adaptive, higher-order, vectorial finite elements for the numerical simulation of the time-harmonic light field in the elementary cell of the periodic array [3]. These methods allow us to investigate resonances of the system.

[1] S. Linden, C. Enkrich, M. Wegener, J. Zhou, T. Koschny, C. M. Soukoulis, *Science* **306**, 1351 (2004).
[2] C. Enkrich, M. Wegener, S. Linden, S. Burger, L. Zschiedrich, F. Schmidt, J. Zhou, T. Koschny, C. M. Soukoulis, *Phys. Rev. Lett.* **95**, 203901 (2005).
[3] S. Burger, L. Zschiedrich, R. Klose, A. Schädle, F. Schmidt, C. Enkrich, S. Linden, M. Wegener, and C. M. Soukoulis, *Proc. SPIE* **5955**, 18 (2005).

Q 35.10 Di 16:30 Labsaal

Phase-resolved pulse propagation in metallic photonic crystal slabs — •Anja Schönhardt[1], Dietmar Nau[1], Hedi Gräbeldinger[2], Christina Bauer[3], and Harald Giessen[2] — [1]Institut für Angewandte Physik, Universität Bonn, 53115 Bonn — [2]4. Physikalisches Institut, Universität Stuttgart, 70550 Stuttgart — [3]Max-Planck Institut für Festkörperforschung, 70569 Stuttgart

We present measurements of the electromagnetic field of ultra-short laser pulses after propagation through metallic photonic crystal structures featuring simultaneous photonic and plasmonic resonances. We used cross-correlation frequency resolved optical gating to measure the complete pulse information, i.e., the envelope and phase of the electromagnetic field. In good agreement, measurements and scattering matrix simulations [1] show a dispersive behavior of the spectral phase at the position of the resonances. Asymmetric Fano-type resonances go along with asymmetric phase characteristics. Furthermore, the spectral phase is used to calculate the dispersion of the sample. Possible application in dispersion compensation is investigated. The behavior of the extinction and the spectral phase can be understood from a fundamental model using the complex transmission amplitude [2,3]. An associated depiction in the complex plane is a new approach in this context [3]. This method promises to be of valuable use also in photonic crystal and filter design, for example with regards to symmetrization of the resonances.

[1] S. Tikhodeev et al., Phys. Rev. B 66, 045102 (2002).
[2] S. Fan et al., Phys. Rev. B 65, 235112 (2002).
[3] A. Schönhardt et al., PRB, to be published.

Q 35.11 Di 16:30 Labsaal

Plasmonic metal-semiconductor-metal photodetectors — •Jurana Hetterich[1], Ulf Geyer[1], Georg Bastian[1], Gero von Plessen[2], and Sergei G. Tikhodeev[3] — [1]Lichttechnisches Institut, Universität Karlsruhe, Kaiserstr. 12, 76131 Karlsruhe, Germany — [2]I. Physikalisches Institut, RWTH Aachen, 52056 Aachen, Germany — [3]A .M. Prokhorov General Physics Institute RAS,Vavilova 38, Moscow 119991, Russia

We have investigated the interplay of plasmonic field enhancement and semiconductor absorption in planar metallic photonic crystals consisting of periodically patterned gold and silver deposited on GaAs/GaInNAs heterostructures. Our goal is to exploit the resulting resonance effects to fabricate a novel class of fast metal-semiconductor-metal (MSM) photodetectors. We have established a new technique for the fabrication of metallic electrodes with dimensions below 100 nm, which are expected to perform two tasks: First, surface plasmon polaritons improve the light transmission through the metal layer, and the local field enhancement associated with these excitations increases the optical absorption in the semiconductor. Second, optically generated electrons and holes are rapidly extracted into the metallic electrodes like in conventional MSM photodetectors. We present theoretical calculations based on the scattering matrix approach and compare the results with experimental spectral and dynamical properties. The resulting ultimate limits of quantum efficiency and bandwidth depending on the absorption properties, RC-times and carrier transit times will be discussed.

Q 35.12 Di 16:30 Labsaal

Properties of Low Refractive Index Supports Made of Mesoporous Silica — •Denan Konjhodzic, Helmut Bretinger, and Frank Marlow — Max-Planck-Institut für Kohlenforschung, D-45470 Mülheim an der Ruhr

Mesoporous silica thin films were synthesized by dip-coating in evaporation-induced self-assembly process. In this modified sol-gel process a nonionic triblock copolymer has been used as a template. The formed structure depends strongly on the processing conditions, especially humidity. Film thickness can be tuned by drawing rate. The structures of two different types of films were investigated by small angle x-ray scattering, transmission electron microscopy and atomic force microscopy [1]. Low humidity allows reproducible synthesis of low refractive index films, which were used as optical waveguide supports.

Here we investigate the influence of processing parameters on their optical properties. Refractive index, birefringence and film thickness were determined by angular-dependent interferometry. Porosity can be determined from refractive index applying different effective media models. The film scattering was characterized in the visible spectral range.

In another sol-gel process very transparent PZT films were synthesized and deposited onto mesoporous films. The compatibility of these films with mesoporous supports is investigated.

[1] D. Konjhodzic, H. Bretinger, U. Wilczok, A. Dreier, A. Ladenburger, M. Schmidt, M. Eich, F. Marlow, Appl. Phys. A 81 (2005) 425

Q 35.13 Di 16:30 Labsaal

QED in an absorbing crystal: the fate of the band structure — •Andreas Kurcz and Carsten Henkel — Institut für Physik, Universität Potsdam, Germany

The Bloch theorem is of fundamental importance for the field quantization in a periodic medium because the quasi-periodic Bloch functions can be used as modes. This approach becomes problematic in the presence of absorption because the Bloch frequencies are complex [1]. We generalize the mode expansion of the field operator using a quantization scheme for the macroscopic Maxwell equations [2,3]. The usual Bloch modes are recovered for vanishing absorption. We also show that the band structure in the (k, ω)-plane gets broadened by the absorption. The calculation is based on the spontaneous decay of a collective state of N two-level systems, similar to the emission by a phased antenna array.

[1] Tip, Moroz, Combes: J. Phys. A 33 (2000) 6223
[2] Huttner, Baumberg, Barnett: Europhys. Lett. 16 (1991) 177
[3] Knöll, Scheel, Welsch: in *Coherence and Statistics of Photons and Atoms*, edited by J. Peřina (John Wiley & Sons, Inc., New York, 2001)

Q 35.14 Di 16:30 Labsaal

Tailoring the Rabi splitting of waveguide-plasmon polaritons — •Christina Bauer[1], Thomas Zentgraf[1], André Christ[1], Jürgen Kuhl[1], Sergei G. Tikhodeev[2], Nikolai A. Gippius[2], and Harald Giessen[3] — [1]Max Planck Institute for Solid State Research, 70569 Stuttgart, Germany — [2]General Physics Institute RAS, Moscow 119991, Russia — [3]4th Physics Institute, University of Stuttgart, 70550 Stuttgart, Germany

Metallic nanowire arrays on top of a waveguiding substrate show a strong coupling between particle-plasmons and waveguide modes. The thereby formed waveguide-plasmon polaritons have a large Rabi splitting of up to 250 meV. By introducing a dielectric spacer layer, the coupling becomes weaker resulting in a smaller Rabi splitting. In our case, we deposited gold nanowires with a width of 100 nm and a height of 20 nm by electron-beam lithography on top of a SiO_2 spacer layer and a 140-nm-thick Indium-Tin-Oxide (ITO) waveguide. The spacer layer thickness was varied between 0 nm and 350 nm. We will show that by increasing the spacer layer thickness the wavefunction overlap between the plasmons and the waveguide modes is reduced and the splitting of the polariton modes becomes smaller. The measurements are in good agreement with simulations done by a scattering matrix method.

Q 35.15 Di 16:30 Labsaal

Tunable anisotropic defect structures in 2D photonic crystals using the Wannier function approach — •Patrick Mack[1], Matthias Schillinger[1], and Sergei Mingaleev[1,2] — [1]Institut für theoretische Festkörperphysik, Universität Karlsruhe — [2]Bogolyubov Institute for Theoretical Physics, Kiev

We present the Wannier function approach for numerically efficient computation of the optical properties of tunable anisotropic defect structures in 2D photonic crystals (PCs). Together with the transfer matrix method we show how waveguide dispersions of tunable anisotropic waveguides in PCs can be efficiently computed. These methods are suitable for modeling and design optimization of photonic devices for building upcoming photonic integrated circuits.

Q 35.16 Di 16:30 Labsaal

Analysis of the resonance properties of Split-Ring Resonators in the near infra-red — •Thomas Zentgraf[1], Carsten Rockstuhl[2], Hongcang Guo[3], Na Liu[3], Christoph Etrich[4], Ingo Loa[1], Karl Syassen[1], Jürgen Kuhl[1], Falk Lederer[2], and Harald Giessen[3] — [1]Max Planck Institute for Solid State Research, Heisenbergstr. 1, 70569 Stuttgart, Germany — [2]Institute for Condensed Matter Theory and Solid State Optics, Friedrich-Schiller University Jena, Max-Wien Platz 1, 07743 Jena, Germany — [3]4th Physics Institute, University of Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany — [4]Institute of Applied Physics, Friedrich-Schiller University Jena, Max-Wien Platz 1, 07743 Jena, Germany

Detailed results of the resonance properties of a metamaterial consisting of single split-ring resonators are presented. We employ transmission and reflection spectroscopy at normal incidence. The influence on the resonances of the important parameters characterizing the geometry of the split-ring resonators are analyzed experimentally. In all cases rigorous diffraction theory is employed for comparing the results with theoretical predictions. It is shown explicitly that the resonances depend solely on the design of the unit cells whose sizes are generally scalable. Besides the magnetic resonance associated with the permeability in such a metamaterial, we likewise focus on its plasmonic resonance. We demonstrate that these permittivity resonances are mostly governed by the baseline wires of the split-ring resonators.

Q 35.17 Di 16:30 Labsaal

Metallo-dielectric photonic crystal superlattices — •T. Zentgraf[1], A. Christ[1,2], J. Kuhl[1], N. Gippius[3], S. Tikhodeev[3], and H. Giessen[1,4] for the collaboration — [1]MPI für Festkörperforschung, Stuttgart, Germany — [2]EPFL, Lausanne, Schweiz — [3]General Physics Institute, Moscow, Russia — [4]Viertes Physikalisches Institut, Universit*t Stuttgart, Germany

We experimentally and theoretically investigate the influence of periodic defects on the transmis- sion properties of one-dimensional metallo-dielectric photonic crystal slabs. The spectral positions and the excitation efficiencies of the quasiguided waveguide modes in the slab are determined by the reciprocal lattice vector and the structure factor of the supercells, respectively. We show that by in- troducing periodic defects in the wire position, the structure factor of the supercells can be strongly modifed. For a polarization of the light perpendicular to the wires, the coupling of higher order Bragg resonances of the lattice structure to localized nanowire plasmon resonances can sensitively controlled by the structure of the supercell. All experimental results show an excellent agreement with the theory.

Q 35.18 Di 16:30 Labsaal

Photonische Kristallfasern mit spezifischer Funktionalität - Herstellung und Anwendung — •Jens Kobelke, Hartmut Bartelt, Kay Schuster, Johannes Kirchhof, Anka Schwuchow, Klaus Mörl und Hartmut Lehmann — Institut für Physikalische Hochtechnologie e.V., Albert-Einstein-Strasse 9, D-07745 Jena

Photonische Kristallfasern (PCF) bieten aufgrund ihrer variablen Mikrolochstruktur zahlreiche Möglichkeiten für interessante optische Faserfunktionsbauelemente. Der hohe Brechzahlkontrast zwischen Glasmatrix (typischerweise Quarzglas) und den Hohlräumen (gefüllt mit Gasen oder anderen fluiden Medien) ermöglicht starke Modifizierungen des Lichtpropagationsverhaltens im Vergleich zu konventionellen Lichtleitfasern. Neue Möglichkeiten zur Erzeugung komplexer PCF-Designstrukturen werden zusätzlich durch den Einsatz dotierter Kernglaskomponenten möglich. Diese Dotierungen erlauben es, viele optische Eigenschaften der PCFs, wie beispielsweise das Modenfeldverhalten, deutlich zu modifizieren. Auf Grund ihrer sehr niedrigen Grunddämpfung und damit möglichen großen Wechselwirkungslänge (bis in den Kilometerbereich) sind PCFs für gaschemosensorische oder auch nichtlinear-optische Anwendungen sehr interessant.