HL 49 Photonische Kristalle II

Zeit: Dienstag 10:45–13:15 Raum: TU P164

HL 49.1 Di 10:45 TU P164

Nonlinear optical experiments on waveguide plasmon polaritons using 5fs pulses — •Matthias W. Klein[1], Thorsten Tritschler[1], Stefan Linden[2], and Martin Wegener[1] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), Wolfgang-Gaede-Straße 1, 76131 Karlsruhe, Germany — [2]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, 76021 Karlsruhe, Germany

We present improved experiments and theoretical modeling of the linear and third-harmonic (TH) optical response of particle plasmons coupled resonantly to a slab waveguide. Our samples consist of lithographically patterned gold stripes on top of a HfO_2 waveguide. This system shows an avoided crossing in linear optics [1] and first nonlinear experiments have been presented [2]. In our experiment we use 5fs pulses from a Ti:Sa oscillator and resolve the TH signal both temporally *and* spectrally. The TH signal exhibits a pronounced beating versus time delay for specific spectral components, an exponential decay for other components, and shows evidence of partial destructive interference. The data fit very well to our theoretical model based on two coupled Lorentz oscillators, which also explains Fano-like lineshapes in the linear spectra. Moreover, we analytically show that the determination of the homogeneous linewidth of particle plasmon ensembles via second or third-harmonic generation experiments is *not* possible, thus contradicting Ref. [3].

[1] A. Christ et al., Phys. Rev. Lett. **91**, 183901 (2003)
[2] T. Zentgraf, A. Christ, J. Kuhl, and H. Giessen, submitted (2004)
[3] B. Lamprecht et al., Appl. Phys. B **69**, 223 (1999)

HL 49.2 Di 11:00 TU P164

Dispersion properties of coupled modes in photonic crystal waveguides — •Alexander Petrov and Manfred Eich — TU Hamburg-Harburg, AB 4-09, Eissendorfer Strasse 38, D-21073 Hamburg, Germany

The power flow redistribution in photonic crystal line-defect waveguides can lead to the appearance of modes with very small group velocities away from the Brillouin zone edge. There are also modes with the power flow distribution similar to the one of conventional dielectric waveguides, these modes propagate with normal group velocities. High values of dispersion can be obtained when different frequencies propagate with different group velocities. This can be achieved by coupling of two different modes in a single waveguide or between two parallel waveguides. Several designs are investigated with band diagrams and time domain simulations. Several hundred ps/nm/mm dispersion without third order dispersion is predicted on the bandwidth of a single wavelength division multiplexing channel.

HL 49.3 Di 11:15 TU P164

Coupled Resonator Optical Waveguides (CROWs) Doped With Nanocrystals — •Björn M. Möller[1], Mikhail V. Artemyev[2], Reinhold Wannemacher[3], and Ulrike Woggon[1] — [1]University of Dortmund — [2]Belarussian State University, Minsk — [3]Universität Leipzig

In this contribution, we study CdSe-doped microspheres of radii between two and four optical wavelengths as building blocks for coupled resonator optical waveguides (CROWs) [1]. Unlike other types of optical waveguides, waveguiding through CROWs is achieved through weak coupling between otherwise localized high-Q optical cavities. The coherently coupled microsphere cavities were prepared by impregnating polystyrene microspheres with a subsurface layer of CdSe nanocrystals [2]. Exactly size-matched microspheres ($<$ 0.1 % size deviation) have been pre-selected via their Mie resonances. The coupled cavities, arranged in linear chains and various two-dimensional geometries are studied by microphotoluminescence spectroscopy and polarization sensitive mode mapping [3]. Waveguides consisting of more than five coherently coupled cavities with radii around 2.25 μm have been achieved.

The financial commitment of the DFG (SPP 1113 - Photonic Crystals) is gratefully acknowledged.

[1] A. Yariv, *et al.*, Opt. Lett. **24**, 711 (1999)
[2] U. Woggon *et al.*, J. Appl. Phys. B **77** (5), 469 (2003)
[3] B. M. Möller *et al.*, Phys. Rev. B **70** (11), 115323 (2004)

HL 49.4 Di 11:30 TU P164

Zur Form holographisch hergestellter Photolackstrukturen — •Daniel C. Meisel[1,2,3] und Martin Wegener[1,2,3] — [1]Inst. f. Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, D-76021 Karlsruhe — [2]Inst. f. Angewandte Physik, Univ. Karlsruhe (TH), — [3]DFG-Centrum für Funktionelle Nanostrukturen

Holographisch hergestellte poröse Photolackstrukturen können als Template für Photonische Kristalle dienen [1,2]. Die Form der Struktur wird üblicherweise als Isointensitätsfläche des Interferenzfeldes beschrieben [1,2,3]. Eine genauere Untersuchung ergab jedoch, dass insbesondere die Form des Motifs der Kristallstruktur trotz gleicher Belichtung stark davon abhängt, wie die Prozessierung des Photolackes durchgeführt wird. Die Translationssymmetrie hingegen ergibt sich zwingend aus dem Interferenzmuster. Es werden zu dieser Frage experimentelle und theoretische Resultate vorgestellt und Konsequenzen daraus diskutiert.

[1] M. Campbell, D. N. Sharp, M. T. Harrison, R. G. Denning und A. J. Turberfield, Nature **404**, 54 (2000)
[2] Yu. V. Miklyaev, D. C. Meisel, A. Blanco, G. von Freymann, K. Busch, W. Koch, C. Enkrich, M. Deubel und M. Wegener, Appl. Phys. Lett. **82**, 1284 (2003)
[3] D. C. Meisel, M. Wegener und K. Busch, Phys. Rev. B **70**, 165104 (2004)

HL 49.5 Di 11:45 TU P164

Electro - Optical Tuning of Photonic Crystal Structures — •Markus Schmidt[1], Manfred Eich[1], Uwe Hübner[2], and Hans-Georg Meyer[2] — [1]Technische Universität Hamburg-Harburg, Materials in Electrical Engineering and Optics, Eissendorfer Str. 38, D-21073 Hamburg — [2]Institut fuer Physikalische Hochtechnologie Jena e.V., Abt. Kryoelektronik, A. Einstein Str.9, D-07745 Jena

Photonic crystals, characterized by a periodic dielectric function, are key elements in future integrated optics. In this respect, electro - optical switches and filters which allow to address different wavelength division multiplexing (WDM) channels are very attractive perspectives in nanophotonics. Therefore, we introduce a new concept which is based on two dimensional photonic crystal resonators with an optically nonlinear waveguide core. The core consists of a high electric field poled polymer, covalently functionalized with nonlinear dye molecules. A quasistatic electric field perpendicular to the slab waveguide axis induces a refractive index change resulting from the Pockels effect. Due to the fact that the spectral properties of the resonant structure of the resonators strongly depend on the refractive index, the transmission characteristic is changed. We realized a finite two dimensional photonic crystal line defect resonator consisting of P(MMA/DR-1) as core material. Shifting of the resonator peak and ac modulations have been observed experimentally. Thus, we demonstrate an electro - optical device made from a nonlinear optical photonic crystal.

HL 49.6 Di 12:00 TU P164

Characterizing and Controlling Photonic Crystal Cavities with Scanning Probe Techniques — •Femius Koenderink, Ben Buchler, and Vahid Sandoghdar — Nano-Optics Group, Laboratory of Physical Chemistry, ETH Zurich, Switzerland

Solid state optical resonators that confine light in ultrasmall volumes currently enjoy wide interest, partly rooted in cavity quantum electrodynamics and partly motivated by a range of applications, including control of spontaneous emission, realization of low threshold lasers, optical switching and sensors. A particular advantage of photonic crystal microcavities is that one can achieve subwavelength cavity dimensions while keeping moderately high quality factors of up to 10^5. In our work we use Scanning Near-field Optical Microscopy to image directly the spatial extent of light. In addition to imaging, we discuss how a near-field probe can be used to manipulate the resonances of a photonic crystal microcavity. By performing Finite Difference Time Domain (FDTD) as well as perturbative analytic calculations, we demonstrate that it is possible to shift the resonance of a microcavity over a large range while maintaining a high quality factor. We discuss prospects of this technique for opto-mechanical switching and tuning of photonic crystals.

HL 49.7 Di 12:15 TU P164

Hin zu Metamaterialien mit negativem Brechungsindex bei optischen Frequenzen — •S. Linden[1], C. Enkrich[2,3], M. Wegener[2,3], J. Zhou[4], T. Koschny[4] und C. M. Soukoulis[4] — [1]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, D-76021 Karlsruhe, Germany — [2]Institut für Angewandte Physik, Universität Karlsruhe (TH), D-76128 Karlsruhe, Germany — [3]DFG-Center for Functional Nanostructures (CFN) — [4]Ames Laboratory and Department of Physics and Astronomy, Iowa State University, Ames, Iowa 50011, U.S.A.

Mittels Elektronenstrahllithographie lassen sich Metamaterialien mit einer magnetischen Resonanzfrequenz von 100 THz realisieren. Die magnetische Antwort der metallischen, unmagnetischen Split-Ring-Resonatoren (SRR) beruht auf der Anregung der LC-Resonanz durch das eingestrahlte Lichtfeld. Für senkrechten Einfall koppelt das elektrische Feld an die Kapazität der SRR. Die experimentell bestimmten Spektren sind in guter Übereinstimmung mit den theoretischen Erwartungen. Zusätzliche numerische Simulationen zeigen, dass die hier vorgestellten Metamaterialien einen Frequenzbereich mit negativer Permeabilität aufweisen, falls eine Ankopplung an die LC-Resonanz über das Magnetfeld erfolgt. Zusammen mit einer negativen Permitivität kann dies zu Metamaterialien mit negativem Brechungsindex führen.

HL 49.8 Di 12:30 TU P164

Herstellung von Metamaterialien mit magnetischer Resonanz für den Telekommunikationsbereich — •C. Enkrich[1,2], F. Perez-Willard[2,3], S. Linden[4], M. Wegener[1,2,3], J. Zhou[5], T. Koschny[5] und C. M. Soukoulis[5] — [1]Institut für Angewandte Physik, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [2]DFG-Center for Functional Nanostructures (CFN), Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [3]Laboratorium für Elektronenmikroskopie, Universität Karlsruhe (TH), 76128 Karlsruhe, Germany — [4]Institut für Nanotechnologie, Forschungszentrum Karlsruhe in der Helmholtz-Gemeinschaft, 76021 Karlsruhe, Germany — [5]Ames Laboratory and Department of Physics and Astronomy, Iowa State Univerisity, Ames, Iowa 50011, U.S.A.

Durch Nanostrukturierung lassen sich Metamaterialien auf der Basis von periodisch angeordneten LC-Schwingkreisen mit magnetischer Resonanz bei Telekommunikationswellenlängen herstellen. Voraussetzung hierfür sind moderne Herstellungsverfahren, die eine minimale Strukturgröße kleiner als 60 nm ermöglichen. Wir haben eine neue Methode getestet, bei der die Proben mit Hilfe eines "Focused Ion Beam Systems" nanostrukturiert werden. Diese bietet gegenüber der Elektronenstrahl-Lithographie [1] den Vorteil, dass das Ergebnis der Strukturierung direkt untersucht und optimiert werden kann ("Rapid Prototyping"). Mit diesem Verfahren wurden Strukturen mit Resonanzwellenlängen unterhalb 1,5 μm hergestellt und die Abhängigkeit von verschiedenen Geometrieparametern untersucht.

[1] S. Linden et al., Science, **306** (2004)

HL 49.9 Di 12:45 TU P164

High quality polymer opals as photonic crystals — •Rudolf Zentel[1], Jianhui Ye[1], Birger Lange[1], Friederike Fleischhaker[1], Marc Egen[1], Frederik Jonsson[2], Sergei Romanov[2], and Clivia Sotomayor Torres[2] — [1]Fachbereich Chemie, Duesbergweg 10-14, Universität Mainz, D-55099 Mainz, Germany — [2]NMRC, Lee Maltings,, Prospect Row, Cork, Ireland

Polymer opals, which are self-assembled from solution, can be made easily, over large areas and with relatively low cost. A possible use of these materials as 3D photonic crystals is -so far- limited by the quality of the crystalline packing and by their refractive index contrast. The refractive index contrast necessary for a "full band gap" might be achievable by the preparation of high refractive index inorganic replica. We want to address here (I) the aspect of the quality of the crystal lattice and (II) the patterning of opaline materials. Concerning the crystal quality (I) we can show that by optimizing the synthesis of colloidal particles (this leads to highly monodisperse colloids) and the crystallization procedure at the same time, large (cm size) high quality colloidal crystals can be obtained. Also heterostructures with different crystal parameters are accessible. Concerning the patterning of opals (II) E-beam lithography can be used for all PMMA based systems. This allows it even to inscribe artificial defects into polymer opals. Also photoprocessable polymer opals are now at hand. Alternatively it is possible to direct the crystallization of the colloids on a substrate to the desired places. This makes it possible to integrate 3D photonic structures into a complex 2D pattern.

HL 49.10 Di 13:00 TU P164

Silicon double inversion of polymeric templates: a route towards functional 3D photonic band gap materials — •Georg von Freymann[1], Nicolas Tétreault[1], Geoffrey A. Ozin[1], Markus Deubel[2,3,4] und Martin Wegener[2,3,4] — [1]Materials Chemistry Research Group, Department of Chemistry, University of Toronto, M5S 3H6, Toronto, Canada — [2]Institut für Angewandte Physik, Universität Karlsruhe (TH), 76128 Karlsruhe — [3]Institut für Nanotechnologie, Forschungszentrum Karlsruhe, 76021 Karlsruhe — [4]CFN, Universität Karlsruhe (TH), 76128 Karlsruhe

We present the successful silicon double inversion of three-dimensional polymeric templates for Photonic Crystals.

In a first step, the high-quality polymer template [1] is infiltrated via a room temperature silica chemical vapor deposition (CVD) process. Plasma etching and thermal combustion subsequently remove the original polymer template. In a second step, the silica template is infiltrated with silicon via Si-CVD with disilane as a precursor. The silica backbone is finally removed by wet chemical etching, leaving behind a replica of the original polymer template cast in silicon. In combination with plasma treatment [2] of the original template, our method opens a facile way for the production of large scale functional 3D Photonic Crystals at telecommunication wavelengths.

[1] M. Deubel et al., Nature Materials 3, 444 (2004)

[2] G. von Freymann et al., Photonics and Nanostructures, in press (2004)