O 71: Plasmonics and Nanooptics III

Time: Thursday 10:30–13:00 Location: GER 38

O 71.1 Thu 10:30 GER 38

Photochromic switching of Fano resonances in metallic photonic crystals — •Felix Bleckmann[1], Sandra Cordes[2], Eduard Maibach[2], Clayton Shallcross[2], Klaus Meerholz[2], and Stefan Linden[1] — [1]Physikalisches Institut, Universität Bonn, Nußallee 12, 53115 Bonn, Germany — [2]Institut fürr Physikalische Chemie, Universität zu Köln, Luxemburger Str. 116, 50939 Köln, Germany

We study switchable metallic photonic crystals composed of a gold grating embedded in a photochromic waveguide. For that purpose we coated the gold grating on top of an ITO-covered glass substrate with the photochromic material XDTE. The interaction of localized plasmonic resonances and delocalized waveguide modes forms waveguide-plasmon polaritons (WPPs) and thus gives rise to a typical Fano line shape in the extinction spectra. The layer thicknesses as well as the shape and period of the gold grating were optimized for the design wavelength of the maximal switching efficiency of the XDTE layer ($\lambda = 610$ nm). By illumination of the sample with UV light, XDTE becomes absorptive in the red part of the spectrum and the damping of the waveguide mode strongly increases. As a result, the Fano dip is strongly suppressed. The low absorpion state is recovered by illumination with orange light. Compared to a simple XDTE film of the same thickness, our approach doubles the switching efficiency at the design wavelength $\lambda = 610$ nm.

O 71.2 Thu 10:45 GER 38

Tuning propagating surface phonon polaritons at mid-infrared frequencies using a phase-change material — •Tao Wang, Peining Li, Ann-Katrin Michel, Dmitry N. Chigrin, Matthias Wuttig, and Thomas Taubner — 1st Institute of Physics (IA), RWTH Aachen University, 52056, Aachen, Germany

Plasmonic antennas are crucial components for nano-optics and have been extensively used to enhance sensing, spectroscopy, light emission, photodetection and others [1, 2]. Nowadays, there is a trend to search for new plasmonic materials with low intrinsic loss at new plasmon frequencies. Alternative to metals, polar crystals have a negative real part of permittivity in the Reststrahlen band and support surface phonon polaritons (SPhP) with weak damping. Recently, we experimentally demonstrated single circular microcavities with well-defined, size-tunable SPhP resonances possessing high Q factors around 60 which are much higher than those in surface plasmon polariton resonators with similar structures [3]. In this work, we present that the dispersion of propagating surface phonon polaritons and the resonances of circular SPhP microcavities can be tuned by the phase change of a thin-layer germanium antimony telluride (GST). The tunability of the propagating SPhP dispersion and resonance pave the way for realizing single active antennas with high Q-factors at mid-infrared frequencies.

[1] L. Novotny et al., Nat. Photonics 5, 83-90 (2011). [2] P. Biagioni,et al., Rep. Prog. Phys. 75, 024402 (2012). [3] T. Wang et al., Nano Lett. 13, 5051-5055 (2013).

O 71.3 Thu 11:00 GER 38

Probing coherent surface plasmon polaritons propagation in gold films using ultrabroadband spectral interferometry — •Dongchao Hou, Heiko Kollmann, Martin Silies, and Christoph Lienau — AG Ultraschnelle Nano-Optik, Institut für Physik, Fakultät V, Universität Oldenburg, 26111 Oldenburg, Deutschland

Surface Plasmon Polaritons (SPP), generated by ultrashort laser pulses at thin dielectric-metal interfaces can transport energy in metallic structures over mesoscopic distances. They can then be used to couple far-field radiation into nanoscopic dimensions reaching extreme light intensities, e.g. at the end of metallic nanotips [1,2].

These SPPs propagate as coherent wavepackets and with propagation properties that are defined by the geometry of the material and the composition of the metal film, e.g. grain boundaries and surface quality. So far, coherent SPP propagation in metallic nanostructures has been studied to a limit extent.

Here, we introduce a new ultrabroadband far-field spectral interferometry method to characterize coherent SPP propagation in metallic nanostructures. Group velocity and dispersion of SPPs are determined with high precision in a wide frequency range in the visible and near-infrared region. Our results shed new light on the interplay between nanostructure geometry and coherent SPP propagation.

[1] S. Schmidt et al., ACS Nano 6, 6040-6048 (2012)
[2] C.C. Neacsu et al., Nano Letters 10, 592-596 (2010)

O 71.4 Thu 11:15 GER 38

Plasmo-Emission: Nonlinear Emission of Electrons from the Plasmonic Field — •Philip Kahl, Andreas Makris, Simon Sindermann, Michael Horn-von Hoegen, and Frank-J. Meyer zu Heringdorf — Faculty of Physics and Center for Nanointegration Duisburg-Essen (CENIDE), University of Duisburg-Essen, 47057 Duisburg, Germany

Nonlinear Photoemission Electron Microscopy (PEEM) using ultrashort (< 20 fs) laser pulses in a normal incidence geometry has been demonstrated to be capable of observing Surface Plasmon Polaritons (SPPs) in space and time. The advantage of the normal incidence geometry over the commonly used grazing incidence geometry is the fringe spacing of the observed Photoemission pattern, which resembles the SPP wavelength. Furthermore, due to the cylindrical symmetry of this incidence geometry, all propagation directions of SPPs on the surface are imaged equally. This opens the possibility to perform Plasmon-Nanooptics measurements, in which SPPs can be observed propagating in different directions and also being reflected, all with sub-wavelength resolution. In the overlap region of two counter-propagating SPPs the formation of a standing wave can be observed. Curved grating couplers can be used to focus two SPPs propagating in opposite directions into a joint focal point. The resulting standing wave pattern has a characteristic time, space and energy signature of SPP-emitted electrons (Nonlinear Plasmo-Emission) and arises without the need of additional light to trigger Photoemission (classical nonlinear Photoemission).

O 71.5 Thu 11:30 GER 38

Interplay between strong coupling and radiative damping of excitons and surface Plasmon polaritons in hybrid nanostructures — Wei Wang[1], Parinda Vasa[1,2], Robert Pomraenke[1], Ralf Vogelgesang[1], Antonietta de Sio[1], •Ephraim Sommer[1], Margherita Maiuri[3], Cristian Manzoni[3], Giulio Cerullo[3], and Christoph Lienau[1] — [1]Institut für Physik, Universität Oldenburg, 26129 Oldenburg — [2]Indian Institute of Technolegy Bombay, 400076 Mumbai — [3]Dipartmento di Fisica, Politecnico di Milano, Milano

Strongly coupled exciton - surface plasmon polariton systems (X-SPP) are of great interest, as they carry a high potential for realizing all-optical plasmonic circuits and devices [1]. For such applications it is imperative to tailor the radiative damping of the coupled system. So far, however, little is known about radiative damping of strongly coupled systems. We therefore study the optical response of a strongly coupled J-aggregate/SPP hybrid [1] by means of coherent angle-resolved spectral interferometry and ultrafast pump-probe spectroscopy. We find large differences between the radiative lifetimes of the hybrid upper (UP) and lower (LP) polariton mode. This indicates that two different energy transfer channels between X and SPP coexist: (i) coherent resonant dipole-dipole interaction [1] and (ii) an incoherent exchange due to spontaneous emission of a photon by one emitter and its subsequent reabsorption by another. The interplay between both pathways results in a pronounced modification of the radiative damping due to the formation of sub- and super-radiant polariton states.

1. Vasa, P. et al, Nature Photon. 7, 128-132, 2013

O 71.6 Thu 11:45 GER 38

k-space resolved nano-imaging with an adiabatic nanofocusing SNOM — •Simon F. Becker, Martin Esmann, Jens H. Brauer, Petra Gross, Ralf Vogelgesang, and Christoph Lienau — Carl von Ossietzky Universität, 26111 Oldenburg, Germany

Adiabatic nanofocusing of surface plasmon polaritons (SPP) propagating on metallic tapers promises to largely reduce unwanted background contributions in apertureless scanning near-field optical microscopy (SNOM) [1,2]. SPP wavepackets launched on a grating-coupler come to a complete halt at the taper apex for an ideal cone-shaped waveguide. Hence, a single point-dipole like light source is formed which bears great potential for nano-imaging and spectroscopy applications.

Recently, we have developed and implemented a k-space imaging technique to characterize this nano-scale light-source and to separate contributions from different taper eigenmodes [3]. Only the lowest, rotationally symmetric eigenmode is expected to contribute to near-fields at the taper apex. Here, using Stokes polarimetry k-space imaging, we isolate the emission from this lowest eigenmode and demonstrate its radial polarization. This allows us to implement a new adaptive optics scheme (based on [4]) to optimize the emission of this fundamental mode. For the first time, we apply k-space resolved polarimetry to nano-imaging of metallic nanostructures and investigate the near-field coupling between probe and sample.

[1] M.I. Stockman, PRL 93, 137404 (2004); [2] S. Schmidt et al., ACS Nano 6, 6040 (2012); [3] M. Esmann et al., BJ Nano 4, 603 (2013); [4] S. Schmidt et al., Opt. Express 21, 26564 (2013).

O 71.7 Thu 12:00 GER 38

Low-temperature scattering scanning near-field optical microscopy — •Jonathan Döring, Susanne C. Kehr, and Lukas M. Eng — IAPP, George-Bähr-Straße 1, 01069 Dresden

We present a fully operating low-temperature scattering scanning near-field optical microscope (LT-s-SNOM) with access to a tunable free-electron laser (FEL) source. The light scattered off an AFM tip strongly depends on the tip-sample near-field interaction, and thus enables mapping of optical properties with a resolution ways below the diffraction limit. The FEL provides spectrally narrow laser radiation in the regime from 4 to 250 μm at a high power density. By the novel and unique combination of LT-s-SNOM and FEL, optical properties of materials can be measured at specific wavelengths as well as at temperatures down to $4K$. Our device is therefore perfectly suited for investigating phase transitions of sample materials featuring phonon resonances in the mid-to-far-infrared regime.

We present measurements of the tetragonal-to-orthorhombic phase transition of barium titanate (BTO), a prototype perovskite ferroelectric material. At room temperature BTO features a characteristic domain pattern, which changes dramatically below the transition temperature of $253K$ as the alteration of the crystal structure is accompanied by a realignment of the spontaneous polarisation axes. We imaged the anisotropy contrast between such ferroelectric domains by LT-s-SNOM [1] above and below the phase transition temperature and confirmed our results by piezo-response force microscopy (PFM).

[1] Kehr et al., Phys. Rev. Lett. 100, 256403 (2008)

O 71.8 Thu 12:15 GER 38

Topological optical-phase transitions in superlensing imaging — •Peining Li[1], Thomas Taubner[1], Jon Schuller[2], Mark Brongersma[2], Chris Fietz[3], Yaroslav Urzhumov[3], Dmitriy Korobkin[3], Gennady Shvets[3], and Rainer Hillenbrand[4] — [1]I. Institute of Physics (IA), RWTH Aachen University, Aachen 52056, Germany — [2]Geballe Lab for Advanced Materials, Stanford University, Stanford, California 94306, USA — [3]Department of Physics and Center for Nano and Molecular Science and Technology, The University of Texas at Austin, Austin, Texas 78712, USA — [4]CIC nanoGUNE Consolider, 20018 Donostia-San Sebastián, Spain

Metamaterials show great capabilities to artificially engineer the light-matter interactions. It has been recently shown that tuning the optical dispersion of metamaterials from ellipsoidal dispersion to hyperbolic dispersion enables a substantial intensity-enhancement of high-spatial-frequency (or high-k) optical fields. In this work, we focus on the phase behavior of high-k fields within the dispersion transition of metamaterials. By using interferometric scanning near-field optical microscopy, we are able to record phase information of the superlens, which is usually lost in the intensity-recording measurements. We experimentally reveal a phase transition of optical near fields in an infrared metamaterial superlens when its dispersion altering between two different kinds of hyperbolic dispersions. Our results illuminate the important role of phase imaging in superlensing, which are also useful for understanding phase behaviors in other metamaterial-based imaging devices such as perfect-lens, hyperlens and meta-lens.

O 71.9 Thu 12:30 GER 38

Near-field nanospectroscopy on perovskite-based superlenses — •Susanne C. Kehr and L.M. Eng — Institut für Angewandte Physik/Photophysik, Technische Universität Dresden, 01061 Dresden

A planar slab with negative permittivity acts as a superlens: it transforms the evanescent fields from the object located on one side of the slab, to form a sub-diffraction-limited image on the opposite side. We study superlenses based on perovskite oxides that show superlensing in the mid-IR. These materials have little material absorption at the wavelengths of interest and, moreover, can be grown epitaxially in high quality, which reduces any losses due to scattering at the interfaces.

We examine multilayer lenses by scattering-type near-field optical microscopy (s-SNOM) in combination with a free-electron laser. This unique setup allows us to address precisely the superlensing resonance, to record the local images created by the lenses, and to measure their spectral response. We found that different perovskites can be combined to form superlenses at different wavelengths that match perfectly theoretical predictions [1]. All of these superlenses form images beyond the diffraction limit. Moreover, we found that the spectral behavior of the lenses reflects a special probe-sample coupling that is mediated by the superlens [2], which might be of interest for functionalized coupling of nanosized objects. Furthermore, the special properties of perovskites such as colossal magnetoresistance, ferroelectricity, and superconductivity may allow for further applications and variations of superlensing.

[1] S.C. Kehr et al., Opt. Mater. Express 1, 1051 (2011).
[2] S.C. Kehr et al., Nat. Commun. 2, 249 (2011).

O 71.10 Thu 12:45 GER 38

Modified Solid Immersion Lens Design for Efficient Light Extraction — •Andreas W. Schell, Tanja Neumer, and Oliver Benson — Humboldt-Universität zu Berlin, Institut für Physik, AG Nanooptik, D-12489 Berlin, Germany

For solid-state single photon emitters, like quantum dots or defect centers like the nitrogen vacancy (NV) center in diamond, it usually is very difficult to efficiently extract the photons. Due to the high refractive index of the host material, many photons are totally internal reflected at the material's planar interface – photons which are basically lost. An elegant way to circumvent this problem is to use of so called solid immersion lenses (SILs). In analogy to the immersion oil in oil immersion microscopy these lenses are made to suppress total internal reflection. Standard SILs are based on a spherical geometry, with the hemispherical SIL being most common.

Here, we will show a design based on ellipsoids and verify its usefulness via three-dimensional finite difference time domain (FDTD) simulations. These structures can be easily produced using the process of two-photon direct laser writing, a process which also allows for direct integration of single photon emitters [1]. Our modified SILs are able to not only collect light, but also do also make use of controlled total internal reflection to direct the light into a very small solid angle while maintaining a high overlap with a Gaussian beam, solving two drawbacks of standard SIL designs at once.

[1] A. W. Schell et al., Scientific Reports 3, 1577 (2013).