O 30: Plasmonics and Nanooptics III

Time: Tuesday 10:30–13:00 Location: H31

O 30.1 Tue 10:30 H31

Time-resolved wave packet observation of surface plasmon polaritons provided by normal incidence photoemission electron microscopy — •Philip Kahl[1], Simon Sindermann[1], Christian Schneider[2], Alexander Fischer[2], Martin Aeschlimann[2], Michael Horn-von Hoegen[1], and Frank-J. Meyer zu Heringdorf[1] — [1]Faculty of Physics and Center for Nanointegration Duisburg-Essen (CeNIDE), Universität Duisburg-Essen, 47057 Duisburg — [2]Department of Physics and Research Center OPTIMAS, University of Kaiserslautern, 67663 Kaiserslautern

In order to observe surface plasmon polaritons (SPPs) in a photoemission electron microscopy (PEEM) experiment, ultrashort (sub 20 fs) laserpulses of 800 nm wavelength are directed onto a surface with plasmonic Ag or Au nanostructures. In the past, non-linear photoemission under grazing incidence was used to obtain a Moiré type contrast of propagating SPPs waves. The possibility of a light incidence normal to the surface of the sample features the prospect of a direct observation of SPP wave fronts as the observed fringes resemble the SPP wavelength. This enables us to track a surface plasmon wave packet propagating at a metal-vacuum interface directly by using phase stabilized, time-resolved experiments under normal incidence conditions. Additionally, the SPP propagation parameters like group and phase velocity as well as the propagation length are measured.

O 30.2 Tue 10:45 H31

Coupled plasmonic waveguide arrays — •Alexander Block, Felix Bleckmann, and Stefan Linden — Physikalisches Institut, Universität Bonn, Nussallee 12, 53115 Bonn

Surface plasmon polaritons (SPPs) are hybrid electromagnetic waves propagating along a metal-dielectric interface. Their effective refractive index can be controlled by adding an additional dielectric on top of the metal. Varying the thickness of the dielectric layer allows us to fabricate structures with complex refractive index profiles. Here, we use negative-tone gray-scale electron beam lithography to define waveguide arrays made of PMMA on top of a gold film.

In our experiment SPPs are excited by focusing laser light onto a grating coupler and the resulting SPP propagation can be visualized by imaging the leakage radiation with a high numerical aperture objective. In contrast to other studies on coupled waveguide arrays our setup can directly observe the field intensities inside the waveguides. The results clearly show the coupling between the waveguides as predicted by the coupled mode theory. The coupling constant can be obtained as a function of the waveguides' thickness and their separation. These results agree well with finite element simulations which are also presented.

O 30.3 Tue 11:00 H31

Manipulation of Airy surface plasmon beams — •Felix Bleckmann[1], Alexander Minovich[2], Jakob Frohnhaus[1], Dragomir N. Neshev[2], and Stefan Linden[1] — [1]Physikalisches Institut, Universität Bonn, Nuassllee 12, 53115 Bonn, Germany — [2]Nonlinear Physics Centre and Centre for Ultrahigh-bandwidth Devices for Optical Systems (CUDOS), Research School of Physics and Engineering, The Australian National University, ACT 0200, Canberra, Australia

Airy plasmons are electromagnetic waves propagating at the interface of a metal and an insulator. In contrast to Gaussian shaped surface plasmons, Airy plasmons are diffractive-free and offer a self-healing behavior. We demonstrate that the propagation of Airy plasmons can be manipulated by adding a supplemental dielectric on top of the metal. More specifically, with controlled variation of the dielectric height a linear gradient of the effective index is producible. The trajectory of Airy plasmons can be controlled this way while preserving their unique non-diffractive properties.

Here, we use negative-tone grey-scale electron beam lithography to fabricate these GRIN plasmonic structures made of PMMA on top of a gold film. The bending of Airy surface plasmons due to the gradient of the effective refractive index is observed by leakage radiation microscopy. Our experimental results are in good agreement with numerical calculations.

O 30.4 Tue 11:15 H31

Morphological tuning of the plasmon dispersion in dielectric-loaded nanofiber waveguides — •Till Leissner[1], Christoph Lemke[1], Jacek Fiutowski[2], Jörn Radke[2], Alwin Klick[1], Luciana Tavares[2], Jakob Kjelstrup-Hansen[2], Horst-Günter Rubahn[2], and Michael Bauer[1] — [1]Christian-Albrechts-Universität zu Kiel, IEAP, 24098 Kiel (Germany) — [2]Mads Clausen Institute, NanoSYD, University of Southern Denmark, Alsion 2, DK-6400 Sønderborg (Denmark)

Understanding the impact of lateral mode confinement in plasmonic waveguides is of fundamental interest regarding potential applications in plasmonic devices. The knowledge of the frequency-wave vector dispersion relation provides the full information on electro-magnetic field propagation in a waveguide. Here two-photon photoemission electron microscopy is used to measure the real part of the surface plasmon polariton dispersion relation in the near infrared spectral regime for individual nanoscale plasmonic waveguides, which were formed by deposition of para-Hexaphenylene (p-6P) based nanofibers on top of a gold film. Characterization by means of scanning electron microscopy and atomic force microscopy provides accurate information on the dimensions of the investigated waveguides and enables us to quantify the effect of mode confinement by comparison with experimental results from continuous p-6P films on a gold substrate and calculations based on the effective index method. Our results show that the structural control of the cross-sectional dimension of a p-6P nanofiber provides a promising means for the customized design of plasmonic waveguides.

O 30.5 Tue 11:30 H31

Propagating and localized surface plasmons probed in a counter-propagating photoemission electron microscopy detection scheme — •Christoph Lemke[1], Till Leissner[1], Alwin Klick[1], Jörn Radke[1], Stephan Jauernik[1], Jacek Fiutowski[2], Jakob Kjelstrup-Hansen[2], Horst-Günter Rubahn[2], and Michael Bauer[1] — [1]Institute for Experimental and Applied Physics, University of Kiel, D-24118 Kiel — [2]Mads Clausen Institute, University of Southern Denmark, DK-6400 Sønderborg

In an interferometric time-resolved photoemission electron microscopy (ITR-PEEM) experiment, the near-field associated with propagating surface plasmon polaritons (SPP) can be locally sensed via interference with ultrashort laser pulses. In this talk, we present ITR-PEEM data of SPP propagation at a gold vacuum interface recorded in a counter-propagating pump-probe geometry. In comparison to former work this approach provides a considerably improved access to the propagation and interaction dynamics of SPP wave packets. The potential of the scheme will be illustrated by two examples: In a first experiment we monitor the propagation of a SPP wave packet along a gold vacuum interface and extract in a rather direct manner characteristic parameters such as phase and group velocity. In a further example the counter-propagating ITR-PEEM scheme is used to investigate the excitation of localized surface plasmons at defined gold nanodots via propagating SPP wave packets. The experiments enable us to directly monitor in detail the interaction dynamics between these two collective modes in time and space.

O 30.6 Tue 11:45 H31

Infrared spectroscopy of single surface phonon polariton resonators — •Tao Wang, Benedikt Hauer, Peining Li, and Thomas Taubner — 1st Institute of Physics (1A), RWTH Aachen University, 52056, Aachen, Germany

Infrared spectroscopy is widely used to identify and characterize molecules. Recently, the sensitivity of infrared absorption spectroscopy was enhanced by several orders of magnitude with metallic optical antennas on dielectric substrates [1-2]. However, phonon-resonant nanostructures promise an even higher field enhancement compared to infrared metallic antennas [3].

In this work, we experimentally investigate the infrared spectroscopy of single surface phonon polariton (SPhP) resonators. The SPhP resonators are individual micro-size holes in a thin gold film fabricated by nanosphere lithography, which is deposited on a SiC substrate. The SPhP resonance of the single holes can be clearly seen from far-field extinction spectra and from near-field optical images. The strong field enhancement combined with the easy fabrication makes single SPhP resonators as a promising candidate for highly sensitive surface enhanced infrared absorption spectroscopy.

[1] R. Adato et al.; PNAS, 106, 19227 (2009)
[2] F. Neubrech et al.; PRL 101, 157403 (2008)
[3] R. Hillenbrand et al., Nature, 418, 159-162 (2002)

O 30.7 Tue 12:00 H31

Magnetic Circular Dichroism PEEM for the study of subwavelength all-optical magnetization switching in TbCo alloys — •Pascal Melchior[1], Markus Rollinger[1], Philip Thielen[1,3], Sabine Alebrand[1], Ute Bierbrauer[1], Christian Schneider[1], Stéphan Mangin[2], Mirko Cinchetti[1], and Martin Aeschlimann[1] — [1]Physics Department and Research Center OPTIMAS, University of Kaiserslautern, Germany — [2]Institut Jean Lamour, Université de Lorraine, France — [3]Graduate School Materials Science in Mainz, Germany

Magnetization reversal using femtosecond laser pulses is a way to control magnetization without any external magnetic field. Combined with plasmonic antenna structures to focus light below the diffraction limit, plasmon-assisted laser-induced magnetization switching has the potential to revolutionize magnetic data storage. In order to study this phenomenon, an experimental method is needed that provides access to both magnetic as well as near-field properties. We show that photoemission electron microscopy (PEEM) combined with magnetic circular dichroism in the two-photon photoemission has the potential to fulfill this role. In particular, we show that high-anisotropy TbCo alloys, which are known to enable optical control over the magnetization, show a decent dichroic contrast in two-photon photoemission PEEM enabling the imaging of magnetic domains. Furthermore, the possibility of plasmon-assisted magnetization switching on structured TbCo films will be discussed.

O 30.8 Tue 12:15 H31

Coherent two-dimensional nanoscopy of nanotextured thin-film Si solar cells — Martin Aeschlimann[1], Tobias Brixner[2], Matthias Hensen[3], •Christian Kramer[2], Pascal Melchior[1], Walter Pfeiffer[3], Martin Piecuch[1], Helmut Stiebig[4], Christian Strüber[3], and Philip Thielen[1] — [1]Fachbereich Physik and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany — [2]Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [3]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld, Germany — [4]Malibu GmbH & Co.KG, Böttcher Str.7, 33609 Bielefeld

The absorption of thin-film solar cells can be enhanced by increasing the effective light path in the absorptive layer via light trapping. We investigated amorphous thin-film Si solar cells with nanotextured internal interfaces by using coherent 2D nanoscopy. This technique combines coherent 2D spectroscopy with photoemission electron microscopy and enables a high spatial resolution below the optical diffraction limit. In our experiments we observed hot-spot photoemission from the Si layer and found line-shape variations of local 2D nanospectra obtained from different spots on the Si surface. These results are consistent with the formation of localized modes of multiply scattered radiation that are responsible for an increased absorption in the Si layer. Furthermore, we fit the measured 2D nanospectra with a damped Lorentzian-oscillator model and received the spatially-resolved information about lifetimes and spectral shifts of localized photonic modes.

O 30.9 Tue 12:30 H31

Real-time observation of ultrafast Rabi oscillations between excitons and plasmons in J-aggregate/metal hybrid nanostructures — Parinda Vasa[1,2], Wei Wang[1], •Ephraim Sommer[1], Melanie Lammers[1], Margherita Maiuri[3], Cristian Manzoni[3], Giulio Cerullo[3], and Christoph Lienau[1] — [1]Institut für Physik and Center of Interface Science, Carl von Ossietzky Universität, 26129 Oldenburg, Germany — [2]Department of Physics, Indian Institute of Technology Bombay, 400076 Mumbai, India — [3]IFN-CNR, Dipartimento di Fisica, Politecnico di Milano, Milano, Italy

Surface plasmon polaritons (SPPs), optical excitations at the interface between a metal and a dielectric, carry significant potential for guiding and manipulating light on the nanoscale. Their weak optical nonlinearities, however, hinder active device fabrication, e.g., for all-optical switching or information processing. Recently, strong optical dipole coupling between SPPs and nonlinear quantum emitters with normal mode splittings of up to 700 meV has been demonstrated. The predicted ultrafast energy transfer between quantum emitters and SPP fields could be a crucial microscopic mechanism for switching light by light on the nanoscale. Here, we present the first real-time observation of ultrafast Rabi oscillations in a J-aggregate/metal nanostructure, evidencing coherent energy transfer between excitonic quantum emitters and SPP fields. We demonstrate coherent manipulation of the coupling energy by controlling the exciton density on a 10-fs timescale, a step forward towards coherent, all-optical ultrafast plasmonic circuits and devices.

O 30.10 Tue 12:45 H31

Collective spontaneous emission of strongly coupled exciton-surface plasmon polaritons — •Wei Wang[1], Parinda Vasa[1,2], Robert Pomraenke[1], Ralf Vogelgesang[1], Margherita Maiuri[3], Cristian Manzoni[3], Giulio Cerullo[3], and Christoph Lienau[1] — [1]Institut für Physik and Center of Interface Science, Carl von Ossietzky Universität — [2]Department of Physics, Indian Institute of Technology Bombay, 400076 Mumbai, India — [3]IFN-CNR, Dipartimento di Fisica, Politecnico di Milano, Milano, Italy

We report on the observation of collective spontaneous emission of strongly coupled excitons (Xs) and surface plasmon polaritons (SPPs) in J-aggregate/metal hybrid nanostructures. The optical response of the system is probed at the field level by angle-resolved spectral interferometry. We find that the strong coupling results in a pronounced modification of the radiative damping due to formation of super- and sub-radiant polariton states. Their ultrafast emission dynamics is measured in real time and is well explained within a coupled oscillator model. Such a strong modification of the radiative damping can open up new directions in coherent active plasmonics.