

HL 39: Plasmonics and Nanooptics IV: Light-Matter Interaction

Time: Tuesday 10:30–13:00

Location: TRE Ma

HL 39.1 Tue 10:30 TRE Ma

Rolled-up active microtubes containing tuneable grating couplers for the excitation of surface plasmon polaritons — ●JAN SIEBELS¹, HOAN VU¹, ALF MEWS¹, STEFAN MENDACH², and TOBIAS KIPP¹ — ¹Institut für Physikalische Chemie, Universität Hamburg — ²Institut für Angewandte Physik, Universität Hamburg

Grating structures can be utilized in order to overcome the momentum mismatch between an incident photon and a surface plasmon polaritons (SPPs) at a metal/dielectric interface. We implemented grating structures with gradually varying effective refractive indices into active microtubes containing GaAs quantum wells. The grating consists of triangularly shaped silver bars—varying the filling-factor in the direction perpendicular to the periodicity. This allows for a position-dependent coupling of the quantum well emission to the SPP. To characterize these systems we implemented a photoluminescence mapping technique by means of a streak camera which allows simultaneous recording of spectral distribution and related decay characteristics. The spatially resolved data reveals spectral shifts and changes of the decay lifetime that can be attributed to localized excitation of SPPs due to the embedded gratings. We gratefully acknowledge financial support by the Deutsche Forschungsgemeinschaft (DFG) via ME3600/1.

HL 39.2 Tue 10:45 TRE Ma

Tip-Enhanced Raman Spectroscopy of a MoS₂ / Au Nanoparticle (2D crystal/Plasmonic) Heterostructure — ●MAHFUJUR RAHAMAN¹, RAUL D RODRIGUEZ¹, GERD PLECHINGER², STEFAN MORAS¹, CHRISTIAN SCHÜLLER², TOBIAS KORN², and DIETRICH RT ZAHN¹ — ¹Semiconductor Physics, Technische Universität Chemnitz, Germany — ²Fakultät für Physik, Institut für Experimentelle und Angewandte Physik, Universität Regensburg, Germany

Tip-enhanced Raman spectroscopy (TERS) has been rapidly improved over the last decade and opened up opportunities to study phonon properties of materials on a nanometre scale. We report on TERS of a 4-layer MoS₂ flake deposited onto a Au nanostructured surface, thus forming a 2D crystal/plasmonic heterostructure. Au nanotriangles are prepared by nanosphere lithography and then MoS₂ is mechanically exfoliated on top of it. The TERS spectra are acquired under resonance conditions at 638 nm excitation using a Xplora/AIST-NT TERS system. We obtain a spatial resolution of 10 nm in TERS imaging. We observe the highest enhancement of the Raman intensity of MoS₂ on top of Au nanotriangles due to the strong electromagnetic confinement between the tip and single triangle. Our results enable us to determine the local strain in MoS₂ induced after the heterostructure formation. The maximum frequency shift of E_{2g} mode is determined to be 3.2 cm⁻¹ which is equivalent to 1% of biaxial strain induced in the film. Our results will help the understanding of the structural and mechanical degrees of freedom to the nanoscale optoelectronic properties of future MoS₂/plasmonic based devices.

HL 39.3 Tue 11:00 TRE Ma

Strong Exciton-Plasmon Coupling on Core-Shell Nanoparticles — ●WOUTER KOOPMAN, FELIX STETE, and MATIAS BARGHEER — Universität Potsdam, Potsdam, Deutschland

Strong-coupling of molecular excitons to localized plasmons in metal nanoparticles offers a new approach for the investigation and utilization of quantum-effects at room temperature. On the other hand, the fabrication of core-shell molecule-metal nanoparticles is possible by well-established, economic wet-chemical methods. Plasmon-exciton coupling could therefore offer an attractive route for the facile implementation of robust, scalable nanoscale quantum systems. This talk will address the presence of strong exciton-plasmon coupling in two simple nanoparticle geometries: core-shell spheres and rods. We will elaborate on the different possible coupling regimes and discuss the pitfalls when one wants to distinguish these experimentally. In particular we show that relying solely on extinction spectrum to classify the coupling regime, as often encountered in literature, can lead to a wrong identification of the regime. In addition, we will address the pronounced dependence of coupling-strength on the particle size and on the dielectric environment and discuss how to use these factors to tailor the coupling.

HL 39.4 Tue 11:15 TRE Ma

SPP-Light Interaction in the Space-Time Domain — ●DAVID JANOSCHKA, PIERRE KIRSCHBAUM, PASCAL DREHER, MICHAEL HORN-VON HOEGEN, and FRANK J. MEYER ZU HERINGDORF — Faculty of Physics and Center for Nanointegration (CENIDE), University of Duisburg-Essen, Duisburg, Germany

Focusing of Surface Plasmon Polaritons (SPPs) with nanooptical elements extends the comprehension of nonlinear phenomena on Au surfaces. We use femtosecond-laser-pulses (<15 fs) to excite SPPs, which can be observed in a direct conceptual visualization in our Photoemission Electron Microscope (PEEM). Focused Ion Beam (FIB) milled structures on Au provide a great control over the shape of the SPP phase fronts. As such, we are able to achieve the formation of a strong SPP-field induced nanofocus with circular shaped excitation structures. This causes highly localized electron emission, exclusively by the SPP-SPP interaction, which was introduced as plasmoemission in previous work.

Here, we investigate the differences between photoemission and plasmoemission. We are in particular interested in the SPP-SPP-interaction in the presence of other nanooptical elements like nanoholes and nanoparticles, especially in the strong field enhancement caused by these nanooptical elements.

HL 39.5 Tue 11:30 TRE Ma

Resonant excitation of isolated helical nanostructures in the visible range — KATJA HÖFLICH², ENNO HANSJÜRGEN¹, HEIKO KOLLMANN¹, SILKE CHRISTIANSEN², CHRISTOPH LIENAU¹, and ●MARTIN SILLIES¹ — ¹AG Ultrafast Nano-Optics, Carl von Ossietzky Universität Oldenburg, Germany — ²Nanoscale Structures and Microscopic Analysis, Helmholtz-Zentrum Berlin, Germany

Circular dichroism is a phenomenon that describes the extinction difference in chiral objects when excited by left and right-handed circular polarized light. While the circular dichroism of single biomolecules is rather low, the signal can be enhanced by several orders of magnitude using artificial, i.e. plasmonic chiral nanostructures. Thus, the study of these plasmonic structures is a vivid field of research. Here, confocal white-light spectro-microscopy is employed to measure extinction spectra of single silver helices with sub-micrometer dimensions fabricated using electron beam induced deposition for left- and right-handed circular excitation. Circular dichroism spectra of isolated right-handed helices show - besides a near-IR resonance for light at the same handedness - a distinct resonance for left-handed circular polarized light in the visible range around 600 nm. While the resonant behavior for the right-handed circular polarized light is expected [1], the emergence of a pronounced left-handed resonance is surprising. Finite element modeling reliably reproduces the observed spectral features and suggests that a pseudo current at the outer surface of the helices locally switches the polarization state of the incident polarization. [1] Gansel et al. Science 325, 1513 (2009)

HL 39.6 Tue 11:45 TRE Ma

The detection of attenuated waveguide modes in SiO₂ on silicon covered with gold-nanoparticles using photo emission electron microscopy — ●ALWIN KLICK¹, RENÉ WAGNER¹, MALTE GROSSMANN¹, LAITH F. KADEM², JOST ADAM³, TILL LEISSNER³, HORST-GÜNTER RUBAHN³, CHRISTINE SELHUBER-UNKEL², and MICHAEL BAUER¹ — ¹Institut für Experimentelle und Angewandte Physik, Christian-Albrechts-Universität zu Kiel — ²Institut für Materialwissenschaft, Christian-Albrechts-Universität zu Kiel — ³Mads Clausen Institut, Syddansk Universitet

We present a time-resolved photoemission electron microscopy study of propagating electromagnetic modes in the UV spectral regime in SiO₂ covered with self-assembled gold nanospheres on a silicon substrate. Comparison with simulations using the finite element method confirms that guided light modes in the SiO₂ slab are detected. Furthermore, we show that the gold nanospheres play a key role in the observation of guided modes using PEEM due to their high electron density substantially enhancing the detected photoemission yield. Analytic calculations which take into account the size of the nanospheres and their distribution on the surface show that plasmonic interactions have negligible impact on the light mode properties.

HL 39.7 Tue 12:00 TRE Ma

Near-field investigation of geometric and material resonances in semiconductor nanowires with doped segments — ●LENA JUNG¹, DMITRIY S. BOYUK², AMAR T. MOHABIR², MICHAEL A. FILLER², and THOMAS TAUBNER¹ — ¹I. Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany — ²School of Chemical & Biomolecular Engineering, Georgia Institute of Technology, Atlanta, Georgia 30332, United States

Doped semiconductors (SCs) allow for tunability of plasmon resonances via gating or doping. We investigate Si nanowires (NWs) with doped segments with infrared near-field microscopy (s-SNOM). In s-SNOM, optical near-fields that are excited via laser-illumination of a metalized AFM tip interact with the sample. This enables to determine the samples dielectric properties with a high resolution only limited by the tip radius (~ 25 nm). By combining the Drude model for doped SCs with models for the tip-sample interaction, carrier properties of the doped SC can be obtained by spectroscopic imaging in the range of a near-field resonance close to the plasma edge. Additionally, the doped segments in the NWs act as resonators for mid-IR light due to their geometry. Localized surface plasmon (LSP) resonances have been observed in the far-field. Different growth conditions revealed differences in the shape of the spectra, explained by variations in the sharpness of the segment boundaries [1]. Goal of our investigations is to distinguish these different effects and to determine carrier properties, boundary sharpness and map the LSP resonance given by the segment geometry.

[1] Chou et al., ACS Nano **9**, 1250 (2015)

HL 39.8 Tue 12:15 TRE Ma

Single-particle spectroscopy of bare and porphyrin-covered silver clusters with multi-photon photoemission electron microscopy — ●KLAUS STALLBERG and WINFRIED DAUM — Institute of Energy Research and Physical Technologies, TU Clausthal, Leibnizstraße 4, 38678 Clausthal-Zellerfeld, Germany

Coupling of optical excitations in dye molecules with plasmonic excitations in metallic nanostructures holds the potential to provide control over light-matter interaction at a nanoscale level. Plasmonic-excitonic coupling has been reported for dye-coated metallic nanoparticles by application of particle-averaging methods. We apply multi-photon photoemission electron microscopy (nP-PEEM) with tunable-laser excitation to study localized surface plasmon resonances (LSPR) of individual silver clusters, which are grown under UHV conditions on silicon substrates. Simulations elucidate the influence of the supporting substrate on the LSPR, most notably an amplification of LSP modes with a polarization normal to the substrate. For particles covered with porphyrin (ZnTPP) the simulations predict the appearance of a second LSPR near the optical absorption (Soret-) band of the ZnTPP molecules, a consequence of coupling between the plasmonic near-field and the excitonic polarization inside the ZnTPP layer. Depending on their spectral positions, both LSP modes are predicted to spectrally repel each other as a result of additional coupling between the LSP modes. In our laser spectroscopic nP-PEEM experiments we observe such spectral shifts for silver particles covered with a ZnTPP layer of only four monolayers.

HL 39.9 Tue 12:30 TRE Ma

Linear ultra-broadband spectral interferometry for probing coherent surface plasmon polariton propagation in the time domain — JUE-MIN YI¹, ●VLADIMIR SMIRNOV¹, DONGCHAO HOU¹, HEIKO KOLLMANN¹, ZSUZSANNA PÁPA², PÉTER DOMBI², SVEN STEPHAN¹, DANIEL ESPELOER¹, CHRISTOPH LIENAU¹, and MARTIN SILIES¹ — ¹AG Ultrafast Nano-Optics, Carl von Ossietzky Universität Oldenburg, Germany — ²Wigner Research Centre for Physics, 1121 Budapest, Hungary

Surface Plasmon Polaritons (SPPs) are evanescent coherent wave packets that can both confine the energy of light to metallic nanostructures and transport energy over mesoscopic distances [1]. They can then be used to generate and process information coded as optical signal to realize nanometer-scale all-optical circuitry. The propagation properties of these SPPs are defined by the geometry and composition of nanostructures. Here, we introduce a new ultra-broadband far-field spectral interferometry method to completely characterize coherent SPP propagation in metallic nanostructures, which allows the reconstruction of the plasmonic field in time domain [2]. Group velocity and dispersion of SPPs are determined with high precision in a broad frequency range in the visible and near-infrared regions, and the propagating SPP field at large distance is thus displayed with high time resolution. Our results shed new light on characterizing the interplay between nanostructure geometry and coherent SPP propagation.

[1] M.L.M. Balistreri, et al., Science 294, p.1080 (2001)

[2] J.Yi, et al., submitted to ACS Photonics (2016)

HL 39.10 Tue 12:45 TRE Ma

(The Road to) Understanding Localization of Light in Nanosponges — ●FELIX SCHWARZ¹, JAN VOGELANG³, GERMANN HERGER³, DONG WANG², HEIKO KOLLMANN³, PETRA GROSS³, ERICH RUNGE¹, CHRISTOPH LIENAU³, and PETER SCHAAF² — ¹TU Ilmenau, Institut für Physik und IMN MacroNano, 98693 Ilmenau — ²TU Ilmenau, Institut für Werkstofftechnik und IMN MacroNano, 98693 Ilmenau — ³Carl von Ossietzky Universität, Institut für Physik and Center of Interface Science, 26129 Oldenburg

Disorder on the nanometer scale can lead to localization of light and huge electromagnetic field enhancement, which in turn can be used for non-linear optics and for the study and exploitation of quantum optical processes. Most recently, long-lived, highly localized plasmons on the surface of nanoporous gold-nanoparticles (nanosponges) with an unmatched excitation efficiency were reported based on photoemission. Surprisingly, first calculations show that on these sponges localization takes place on the same length scale as the typical pore size. To optimally tailor the disorder for potential applications and increase the understanding of this unusual localization process, we systematically examine the influence of the specific type of disorder. Far-field scattering and near-field properties are calculated for different correlation functions and filling fraction of the sponges. Furthermore, a multiscale approach is presented, where parts of the surface can be simulated with increased resolution while the antenna resonances are evaluated in an effective-medium picture. Very good agreement with experimental data regarding the field enhancement and lifetime is reported.