O 77: Poster: Plasmonics and Nanooptics

Time: Wednesday 18:15–20:30 Location: Poster A

O 77.1 Wed 18:15 Poster A

Spectroscopic investigation of periodic plasmonic superstructures — •Ekaterina Ponomareva and Matthias Karg — Heinrich-Heine-University Düsseldorf, Physical Chemistry I, Düsseldorf, Germany

Nanoparticles with a plasmonic metal core and a soft cross-linked hydrogel shell spontaneously self-assemble at an air/liquid interface forming periodic monolayers [1]. These layers can be transferred on glass substrates yielding substrate-supported superstructures with hexagonally arranged plasmonic nanoparticles at inter-particle distances of a few hundred nm. Due to the spatial proximity and the periodicity of the array, localized surface plasmons of metal cores can couple to diffractive modes and thus support surface lattice plasmon resonances [2]. By embedding the monolayer into a gain-medium these resonances can be enhanced.

Here we will demonstrate the angular-dependent optical behavior of periodic plasmonic monolayers. UV-vis measurements show different optical properties for dilute particles in aqueous dispersion, the assembled monolayers and the monolayers upon embedding in a gain matrix. A home-made lasing-spectrometer was used to investigate the collective optical response of the plasmonic lattices in dependence on the detection and incident angle. With the set-up it is possible to observe the near-field and radiative plasmonic coupling effects in colloidal monolayers.

[1] K. Volk et al., Adv. Mater. 24 (2015), 7332

[2] K. Volk et al., Adv. Optical Mater. 5 (2017), 1600971

O 77.2 Wed 18:15 Poster A

Development of an optical near-field microscope — •hamed abbasi[1,2], igor shavrin[1], and klas lindfors[1] — [1]University of Cologne, Department of Chemistry, Cologne, Germany — [2]University of Bonn (Bonn-Cologne Graduate School for Physics and Astrophysics), Bonn, Germany

Scanning near-field microscopy is an outstanding method to investigate the features of materials on the deeply subwavelength scale. We develop and characterize a probe consisting a single gold nanoparticle for scanning near-field optical microscopy. The tip-particle system is locked to the surface within a distance of a few nanometers. After locking the distance, the surface can be scanned by using a 3-D Piezo stage to locally enhance light-matter interactions.

O 77.3 Wed 18:15 Poster A

Plasmonic fluorescence enhancement in cyanobacterial Photosystem I — •Daniel Fersch[1], Sebastian Pres[1], Bernhard Huber[1], Viktor Lisinetskii[1], Heiko Lokstein[2], and Tobias Brixner[1] — [1]Institut für Physikalische und Theoretische Chemie, Universität Würzburg, 97074 Würzburg, Germany — [2]Department of Chemical Physics and Optics, Charles University Prague, 121 16 Praha 2, Czech Republic

We investigate plasmon-enhanced fluorescence in thin films of Photosystem I (PS I) spin-coated with Au nanorods. Single hot spots attributed to the plasmonic fluorescence enhancement were observed by laser-scanning fluorescence microscopy. The extremely weak fluorescence signal of PS I excited by a HeNe laser is filtered by lock-in amplification.

The role of PS I is light-induced electron donation, so an interesting question is whether plasmonic interaction has an effect on the rate of charge separation, and thus photoelectron emission. To measure this we plan to extract the electrons from the PS I using photoemission electron microscopy. Finally, we intend to combine this method with ultrafast multidimensional spectroscopy to track transfer dynamics in space and time [1].

[1] M. Aeschlimann et al., Science 333, 1723 (2011)

O 77.4 Wed 18:15 Poster A

Plasmonic cavities and resonators in crystalline particles: fabrication and optical properties — •Manuel Gonçalves[1], Amos Kiyumbi[1], Joseph Iduwe[1], Frederike Erb[1], Gregor Neusser[2], Christine Kranz[2], Othmar Marti[1], and Kay Gottschalk[1] — [1]Ulm University - Institute of Experimental Physics, Ulm, Germany — [2]Ulm University - Institute of Analytical and Bioanalytical Chemistry, Ulm, Germany

Crystalline particles of gold and silver offer the best quality for the fabrication of plasmonic cavities, milled by focused ion beam (FIB). Due to the smoothness of the metal surface and consequent low absorption and radiation losses, groove cavities and other resonators can strongly enhance the near-fields and reach large Purcell factors. We have investigated theoretically and experimentally the reflection spectra of arrays of cavities milled in gold and silver particles and the fluorescence of dye molecules localized near silver particles. Metasurfaces formed by arrays of cavities may work as a band selective absorbing filter, or as a polarizer. Moreover, we have found that the sharp edges of the silver particles strongly enhance the dye fluorescence.

O 77.5 Wed 18:15 Poster A

STM-based time domain analysis of exciton generation in thin C_{60} films in the limit of single charge injection. — •Anna Rosławska[1], Pablo Merino[1], Christoph Grosse[1,2], Christopher Leon[1], Markus Etzkorn[1], Klaus Kuhnke[1], and Klaus Kern[1,3] — [1]Max-Planck-Institut für Festkörperforschung, Heisenbergstraße 1, 70569 Stuttgart, Germany — [2]NanoPhotonics Centre, Cavendish Laboratory, University of Cambridge, Cambridge CB3 0HE, UK — [3]École Polytechnique Fédérale de Lausanne, 1015 Lausanne, Switzerland

The performance of organic light emitting diodes is controlled by charge and exciton dynamics which can be probed by time-resolved spectroscopies. Many methods, however, are sensitive only to mesoscopic transport properties for large charge density distributions. Here, we explore locally the single charge and single exciton regime using time-resolved scanning tunneling microscope-induced luminescence (TR-STML). We study excitonic emission centers (ECs) in a model system of C_{60} thin films on Au(111). ECs exhibit single photon emission due to single exciton trapping near structural defects. We apply 100 ns voltage pulses to turn the photon emission from the EC on and off and record time-resolved electroluminescence as a function of tip-sample distance. The observed dynamics is due to single electron and single hole injection and can be analyzed by employing a kinetic model which perfectly fits the recorded transients. The electric field dependence of the obtained time constants allows characterizing the energy barrier for electron injection at the C_{60} - Au(111) interface.

O 77.6 Wed 18:15 Poster A

Circular dichroism calculation of plasmonic nanohelices by boundary element method — •Daniel Nürenberg and Helmut Zacharias — Physikalisches Institut & Center For Soft Nanoscience, Münster, Germany

We present calculations on absorption, scattering and near-fields of plasmonic Ag, Cu and Ag:Cu alloy nanohelices from the UV to the near infrared of the optical spectrum. The calculations were carried out with a boundary element approach using the MNPBEM toolbox [1]. The inherent chirality of the nanohelices leads to a strong circular dichroism (CD). Furthermore we study the CD regarding different geometries, i.e. the size of the nanohelices in pitch and length around 100 nm. We compare the results for free helices and for helices attached to a silicon substrate and find for both very similar distributions of the intensities on the surface of the particles. The simulations can be compared with experimental reflectivity measurements.

[1] J. Waxenegger, A. Trügler, and U. Hohenester, Comput. Phys. Commun. 193, 138 (2015).

O 77.7 Wed 18:15 Poster A

Shaping Femtosecond Laser Pulses for Plasmonics — •Christoph Schnupfhagn, Moritz Heindl, Jonas Albert, and Markus Lippitz — Experimental Physics III, University of Bayreuth, Germany

Pulse shapers allow to modify phase and amplitude of ultrafast laser pulses in an almost arbitrary manner. This is especially favourable for nonlinear spectroscopy as electric fields for multiphoton processes can be precisely engineered. Combined with plasmonic nanostructures the optical near field can be controlled in space and time. In our experiment, we use a liquid crystal based spatial light modulator to reshape 8fs laser pulses in frequency space. The challenge is to couple the pulses into a high NA microscope without significant broadening in time domain. Here we present our experimental setup for pulse compression in the focal plane. Moreover, we give an overview how the spatiotemporal control of optical fields can be utilized in future experiments.

O 77.8 Wed 18:15 Poster A

Simulation of plasmonic nanoantennas excited by orbital angular momentum light — •Richard M. Kerber[1,2], Jamie M. Fitzgerald[2], Sang Soon Oh[2,3], Ortwin Hess[2], and Doris E. Reiter[1,2] — [1]Institut für Festkörpertheorie, Universität Münster, 48149 Münster, Germany — [2]Department of Physics, Imperial College London, London SW7 2AZ, United Kingdom — [3]School of Physics and Astronomy, Cardiff University, Cardiff CF24 3AA, United Kingdom

Orbital angular momentum light beams offer the possibility to encode additional information in the phase of the light beam, which makes them attractive for future communication technology. Here we study the interaction of orbital angular momentum light with plasmonic nanostructures and analyse the excited modes. Based on three different numerical and analytical methods, we show that for various combinations of polarization and orbital angular momentum of the incident light beam the scattering cross-section of rotation-symmetrical nanorod antennas displays different resonance modes [1]. The modes can be classified into bright and dark modes with their own resonance wavelengths. We compare the simulation results of the boundary element method with finite-difference time-domain simulations. Additionally we compare the numerical results with our analytical line antenna model. We discuss advantages and disadvantages of the three different approaches. [1] Kerber et al., ACS Photonics, 4, 891-896 (2017)

O 77.9 Wed 18:15 Poster A

Spatial and temporal separation of plasmon-induced hot carriers by time- and energy-resolved PEEM — •Michael Hartelt[1], Anna-Katharina Mahro[1], Tobias Eul[1], Benjamin Frisch[1], Eva Prinz[1], Deirdre Kilbane[1,2], Benjamin Stadtmüller[1], Mirko Cinchetti[1,3], and Martin Aeschlimann[1] — [1]Department of Physics and Research Center OPTIMAS, TU Kaiserslautern, Germany — [2]School of Physics, University College Dublin, Ireland — [3]Experimentelle Physik VI, Fakultät Physik, TU Dortmund, Germany

The generation of hot carriers through the internal decay of plasmons in metallic materials has received considerable attention lately, due to its wide range of potential applications [1]. Understanding the differences between photo-induced and plasmon-induced hot electrons is essential for the construction of devices for plasmonic energy conversion. We use a two-color femtosecond pump-probe scheme in time-resolved 2-photon-photoemission (TR-2PPE) to address the population dynamics of excited electrons in metals. We are able to separate the spectroscopic signature of the pure plasmon-induced hot carriers from that of directly photo-excited carriers by following the spatial evolution of photoemitted electrons with energy-resolved Photoemission Electron Microscopy (PEEM) during the propagation of a Surface Plasmon Polariton (SPP) along an Au surface. This allows us to study plasmon-induced hot carrier dynamics on the femtosecond and nanometer scale.

[1] Brongersma et al., Nature nanotechnology 10.1 (2015)

O 77.10 Wed 18:15 Poster A

Ellipsometric investigation of the interaction of surface and localized plasmons and registration of their splitting — •Eugene Bortchagovsky — Institute of Semiconductor Physics of NAS of Ukraine, pr. Nauki 41, Kyiv 03028, Ukraine

Two interacting resonances can hybridize and split with energy gap between two hybridized dispersion curves instead of their intersection. We used ellipsometry to investigate the interaction of surface plasmon with localized resonances of nanoparticles deposited on the surface.

Ellipspmetric measurements were made as in the standard configuration with external reflection as in the Kretschmann geometry with internal reflection. Spherical gold particles from "Nanopartz" were deposited from solution on gold films with the thickness of about 40nm deposited on BK-7 slides. For measurements in Kretschmann geometry slides were attached to BK-7 rectangular prism by matching index liquid from "Cargil". Dispersion curves were restored from the position of dips in measured ellipsometric spectra of "psi" angle for the system with nanoparticles with the diameter of 50nm.

Presented results clearly demonstrate existence of few plasmon resonances localized on nanoparticles. The third resonance may be multipolar in addition to two (longitudinal and transverse) dipolar ones lifting of the degeneration of which is produced by the interaction with surface. All localized resonances hybridize with the surface plasmon producing splitting instead of the crossing of initial dispersion dependences. Parts of dispersion curves obtained at external and internal reflection join each other.

O 77.11 Wed 18:15 Poster A

Grating Coupling to Surface Phonon Polaritons with an Infrared Free-Electron Laser — •Marcel Kohlmann, Nikolai C. Passler, Martin Wolf, and Alexander Paarmann — Fritz-Haber-Institut der Max-Planck-Gesellschaft

When coupling infrared electromagnetic waves and optical phonons at the surface of a polar dielectric material, surface phonon polaritons (SPhPs) can be created within the Reststrahlen band between transversal and longitudinal optical phonons. SPhPs have a longer lifetime than surface plasmon polaritons (SPPs) which makes them promising candidates to overcome the loss problems assocciated with the short life times of SPPs. Since surface polaritons are non-radiative large momentum states, they cannot be excited from free space, but instead require nanostructures[1], prisms[2] or gratings[3] to provide the extra momentum.

Here we use gratings etched into a SiC surface to excite propagating SPhPs with a infrared free electron laser. Reflectance measurements are employed to optimize the SPhP excitation efficiency of the grating structures. Finally, we probe the resonant light emission from a second grating of different period of well-defined distance from the first grating to investigate the propagation of the SPhPs at a flat surface.

[1] Razdolski et al., Nano Lett. 16, 6954 (2016)
[2] Passler et al., ACS Photonics 4, 1048 (2017)
[3] Hafeli et al., J. Appl. Phys. 110, 043517 (2011)

O 77.12 Wed 18:15 Poster A

Imaging of near fields on nanoscopic scale by using Atomic Force Microscopy (AFM) — •Christoph Bauschke, Kai Wardelmann, Sven Kraft, Ingo Barke, and Sylvia Speller — University of Rostock, Institute of Physics, 18059 Rostock, Germany

The optical tweezers phenomenon illustrates, that light is applying an optically induced forces while interacting with matter [1]. Our aim is the determination of optically induced forces by using Atomic Force Microscopy and illumination of metal nanostructures by time-modulated light. A lock-in amplifier serves to determine the share of the cantilever deflection, induced by light. On triangular islands of Au an optically induced effect on the cantilever deflection appears to be present, however this contrast is neither depending on the shape nor fully vanishing during dark phases suggesting other effects being involved. Improvements with respect to embedding of the metal nanostructures, better resonance between laser light and plasmon frequency of nanopartciles, and using more appropriate modulation frequencies are applied. Respective deflection maps could reveal dedicated light-induced features.

[1] Maragò et al., Nature Nanotechnology 8, (2013)

O 77.13 Wed 18:15 Poster A

Theory of coherent energy transfer between molecular exciton and gap plasmon induced by a scanning tunneling microscope — Lei-Lei Nian and •Jing-Tao Lü — School of Physics and Wuhan National High Magnetic Field Center, Huazhong University of Science and Technology, 430074 Wuhan, P. R. China

The coupling between molecular exciton and gap plasmons plays a key role in single molecular electroluminescence induced by a scanning tunneling microscope(STM). But it has been difficult to clarify the complex experimental phenomena. By employing the nonequilibrium Green's function technique, we propose a general theoretical approach to understand the light emission from single molecule and gap plasmons near a metal surface excited by the tunneling current. It is shown that the coherent energy transfer between the gap plasmon and molecular exciton leads to a significant Fano resonance when the molecule is located in the proximity of the STM tip. Different line shapes have been observed in recent experiemnts. Being applied to these experiments, our theory can provide a consistent and quantitative account of the experimental results from an energy transport point of view. This theoretical approach allows one to explain and predict the complex energy transfer processes, such as field-matter interaction and quantum interference, important for the further development in this field.

O 77.14 Wed 18:15 Poster A

Density matrix formalism in ultrafast electron microscopy —

•Sergey V. Yalunin, Katharina E. Priebe, and Claus Ropers — University of Göttingen, 4th Physical Institute, Göttingen 37077, Germany

Electron-photon interactions are currently a subject of high interest in ultrafast electron imaging and microscopy [1]. Beyond the use in optical near-field imaging, such interactions may be important for the observation of quantum entanglement dynamics in solids, in the context of pump-probe experiments, using the free single-electron state as a quantum probe. However, this requires both a proper theoretical description of the underlying quantum processes and a quantum reconstruction algorithm of the electron state. Due to the limited number of projective measurements, the quantum reconstruction becomes essentially ill-posed in the sense that the matrix transformation describing the measurement does not have a bounded inverse. To demonstrate the feasibility of quantum reconstruction, we consider a situation where electrons initially prepared in a pure quantum state interact with two partially coherent laser pulses focused on a nanostructure. We reconstruct the final mixed quantum state of the electron ensemble and the properties of the laser field, contrasting the results with recent data [2] obtained with the Göttingen Ultrafast Transmission Electron Microscope (UTEM).

[1] B. Barwick, and A. H. Zewail, Nature 462, 902-906 (2009).
[2] K. E. Priebe et al., Nature Photonics 11, 793-797 (2017).

O 77.15 Wed 18:15 Poster A

Simulations of the magneto-plasmonic response of hybrid Bi-YIG/Au nanostructures — •Philipp Lang, Spiridon D. Pappas, and Evangelos Th. Papaioannou — Fachbereich Physik and Landesforschungszentrum OPTIMAS, Technische Universität Kaiserslautern, Germany

The strong localization of light, which can be induced by surface plasmons, enhances the magneto-optical response of ferromagnetic materials [1]. In this work, we simulated the magneto-optical response of bismuth substituted yttrium iron garnet (Bi-YIG) thin films containing gold nanoparticles (AuNPs) with the aid of the simulation Software CST STUDIO. Specifically, the longitudinal magneto-optical Kerr effect (L-MOKE) has been simulated from the orthogonal components of the radiated electric field in the far field region and the results have been compared with the experimental. In order to explain the trend of the anomalous Kerr effect, which is attributed to the localization of the electric field by the AuNPs, the Near Field enhancement has been calculated and correlated to the Far Field results. The Near and Far field simulations have been performed by using unit cell boundary conditions for different angles, as well as for different wavelengths of the incident light.

[1] M. Rollinger et al., Nano Lett. 16, 2432 (2016).

O 77.16 Wed 18:15 Poster A

Scanning near-field optical spectroscopy with an inline interferometer for probing local absorption — •Jens Brauer, Jinxin Zhan, Petra Gross, Manuela Schiek, and Christoph Lienau — Carl von Ossietzky Universität Oldenburg

Combining spectroscopy methods with nanoscale probing techniques such as scanning near-field optical microscopy (SNOM) helps to measure vibrational fingerprints, quantifiy chemical composition or study the interaction of light with plasmonic nanoparticles or hybrid nano structures. Until now local spectra on the nanoscale are mainly measured indirectly, for example by repeated SNOM scans using monochromatic light and tuning the wavelength of the laser or by Fourier transform interferometry techniques. Nanoscale spectroscopy with SNOM is thus limited either in spectral resolution or in scan speed. A direct spectrometer approach is usually thought not to be possible since high-frequency modulation techniques are needed for background suppression.

We demonstrate a way to suppress background fields over a broad spectral range employing an inherently stable in-line interferometer in a homodyne detection scheme. In combination with a fast line camera it allows to directly acquire spectra employing existing modulation techniques. We record near-field spectra with a spatial resolution of 20 nm and reveal a spectral variation below the resolution limit of widefield microscopy. With a microscopic model of the sample we relate this spectral variation to a local change of the morphology.

O 77.17 Wed 18:15 Poster A

Light trapping and localization in a-Si:H absorber layers with tailored nanotextures — Martin Aeschlimann[1], Felix Becker[2], Tobias Brixner[3], •Benjamin Frisch[1], Michael Hartelt[1], Matthias Hensen[3], Thomas H Loeber[4], Walter Pfeiffer[2], Sebastian Pres[3], Bernd Stannowski[5], and Helmut Stiebig[2] — [1]Fachbereich Physik and Research Center OPTIMAS, TU Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern — [2]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld — [3]Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg — [4]Nano-Structuring-Center, Erwin-Schrödinger-Str. 13, 67663 Kaiserslautern — [5]Helmholtz-Zentrum Berlin, PVcomB, Schwarzschildstr. 3, 12489 Berlin

The enhanced absorbtion for near-IR wavelengths in hydrogenated amorphous silicon (a-Si:H) thin films deposited on a nanotextured zinc oxide (ZnO) surface has been attributed to thermionic emission caused by Anderson localization of light [1]. FDTD simulations reveal that light localization only occurs for distinct spatial frequency ranges of surface roughness. Here a focused ion beam based fabrication technique is applied to tailor the ZnO towards a disordered system with enhanced absorption. The actual light trapping and absorption is investigated using time- and energy-resolved electron emission microscopy. We observe localized modes and high nonlinearities supporting the theory of thermionic emission after excitation with fs-pulses of 800 nm wavelength. [1] Nature Photonics 9, 663-668 (2015)

O 77.18 Wed 18:15 Poster A

Three-dimensional plasmonic nanostructure design for boosting photoelectrochemical Activity — •rui xu, liaoyong wen, zhijie wang, huaping zhao, shipu xu, yan mi, yang xu, max sommerfeld, yaoguo fang, and yong lei — Am Ehrenberg 2, 98693 ilmenau

An innovative approach is presented to construct three-dimensional pillar/truncated-pyramid (PTP) plasmonic nanostructure arrays. A CdS film on the Au PTP demonstrates the advantage of PTP plasmonic structures for light trapping, leading to about 3 and 2 times enhancement photocurrent density at -0.4 V vs. RHE as compared with a planar CdS/Au and pillar electrodes, respectively. A wide spectral range of enhancement was achieved, originating from photonic and plasmonic modes. Studies on the aspect ratio of P/TP and different thickness of CdS were carried out. The nanostructures are highly robust and can easily be utilized in other semiconductor thin film photovoltaic and photoelectrochemical cells.

O 77.19 Wed 18:15 Poster A

Metallic Phase-Change Materials for Nanoantenna Resonance Tuning — •Antonios Antonopoulos, Andreas F. Hessler, Martin Lewin, Tobias W. W. Mass, Matthias Wuttig, and Thomas Taubner — Institute of Physics (IA) RWTH Aachen

Nanostructured metasurfaces have the ability to manipulate light fields. Their properties depend on the size and position of nanostructures, which are generally fixed after fabrication.

Phase-change materials (PCMs) can be used to adjust the, otherwise fixed, properties of metasurfaces [1]. PCMs show a large contrast between their metastable crystalline and amorphous phases. So far, mainly PCMs that are dielectric in both phases in the infrared have been used [2].

Here, we apply a different kind of PCM to metasurfaces. In the infrared, In_3SbTe_2 (IST) is dielectric in the amorphous phase, but metallic in the crystalline phase. Simulations suggest that by switching IST deposited in the gap between neighboring nanostructures with a focused laser beam, we can conductively connect them. Moreover, we present results on metallic nanoantennas composed of crystalline IST which were directly written into a thin film of amorphous IST with a pulsed laser.

In general, metallic PCMs provide exciting new opportunities for the functionalization of metasurfaces.

[1] M.Wuttig et al., Nat. Photon. 11, 465 (2017)
[2] A.-K. U. Michel et al., Adv. Optical Mater. 5, 1700261 (2017)

O 77.20 Wed 18:15 Poster A

Investigation of antenna design for improving the number of switching cycles of phase-change material covered nanoantennas — •Achim Strauch, Andreas F. Hessler, Henrik Wördenweber, Matthias Wuttig, and Thomas Taubner — Institute of Physics (IA) RWTH Aachen

Phase-change materials (PCMs) have been shown to be a useful tool to provide metasurfaces with an active functionality. Since they generally have large optical contrasts between their metastable amorphous and

crystalline phases, a change in the phase of a thin film of PCM ontop of a metasurface greatly influences its optical properties [1].
This phase-change can be controlled very locally around individual nanostructures with a focussed pulsed laser by either using long, low-energy or short, high-energy pulses for crystallization or amorphization, respectively. The transition between the two phases should be possible with a high number of switching cycles [2].
In our work, we investigate the influence of the design of nanostructures covered with the PCM $Ge_3Sb_2Te_6$ on the number of achievable switching cycles. Specifically, we compare rod with slit antennas and consider the influence of the thickness of a protecting capping layer.
A high number of switching cycles is an important prerequisite for nanophotonic applications of PCMs.

[1] M. Wuttig et al., Nat. Photon. 11, 465 (2017)
[2] M. Wuttig et al., Nat. Mater. 6, 824 (2007)

O 77.21 Wed 18:15 Poster A

Photon Correlation Measurements on Quantum Dots — •Lok-Yee Yan, Manuel Peter, and Stefan Linden — Physikalisches Institut, University of Bonn, Nußallee 12, D-53115 Bonn, Germany

Semiconductor quantum dots (QDs) can be used as single photon emitters in various applications. In our group we have developed a lithographic method that allows us to deposit a controllable number of colloidal semiconductor QDs on freely definable sites on the substrate. Lately, we improved this method to the reliable placement of single QDs which could be confirmed by electron micrographs. In order to demonstrate photon-antibunching of the fluorescence of a single QD, we are performing a Hanbury-Brown-Twiss experiment (HBT) which leads to the direct measurement of the second-order correlation function $g^{(2)}(\tau)$. In the HBT the fluorescence is divided by a 50:50 beam splitter and detected by two avalanche photodiodes. Both output signals of the photodiodes are fed into a Time-Correlated Single Photon Counting unit. The correlation function $g^{(2)}(\tau)$ can then be extracted by measuring the histogram of the time difference τ between the two signals. As a clear indicator for photon-antibunching, we expect a significant decrease of $g^{(2)}(0)$.

O 77.22 Wed 18:15 Poster A

Improved Dynamic Range Imaging in Time-Resolved 2PPE PEEM — •David Janoschka, Pascal Dreher, Michael Horn - von Hoegen, and Frank Meyer zu Heringdorf — Faculty of Physics and Center for Nanointegration (CENIDE), University of Duisburg-Essen, Duisburg, Germany

The commonly used detector for low energy electron microscopy (LEEM) or photoemission electron microscopy (PEEM) is a combination of a multichannel plate (MCP) with a phosphor screen. An optical CCD or CMOS camera is then used to film the microscope image off the screen. In time-resolved imaging of nonlinear electron emission from strong plasmonic fields (Plasmoemission) such detection scheme reaches its limitations due to the high contrast and the dramatic intensity variations in the data on a sub-micrometer scale: simply due to the construction of a MCP/Screen combination, every bright small emission spot on the MCP is surrounded by a disc of slightly increased intensity ("halo"), which makes a quantitative analysis of the electron yield between two bright emission spots almost impossible. On the poster we report on a recent upgrade of the SPE-LEEM microscope at the University of Duisburg-Essen, during which the MCP/screen combination was replaced with a fiber-coupled CMOS sensor. We will show PEEM and LEEM images obtained with the new detector and we will compare the performance of the new detector with the previously used MCP setup. The new detector provides us with a much higher dynamic range, with less noise, and imaging without halos.

O 77.23 Wed 18:15 Poster A

Imaging with ultrathin nonlinear metalenses — •Christian Schlickriede[1], Philip Christian Georgi[1], Guixin Li[3], Shuang Zhang[2], and Thomas Zentgraf[1] — [1]Universität Paderborn, Paderborn, Germany — [2]School of Physics and Astronomy, University of Birmingham, United Kingdom — [3]Department of Materials Science and Engineering, Southern University of Science and Technology, China

In our approach we fabricate a new kind of plasmonic metalens, which is solely working in the nonlinear regime by instantaneous frequency conversion for the incident near-infrared light. Therefore, we use the concept of a nonlinear geometric phase emerging from the configuration of meta-atoms with specific rotational symmetry. The designed nonlinear metalenses are ultrathin devices with a thickness of only 30 nm. Depending on the incident circular polarization of light, the phase profile for the nonlinear harmonic generation process can be switched between convex and concave. In the experiments, we determine the formation of the real and virtual focal planes for illumination with Gaussian beams and we demonstrate nonlinear imaging abilities that giving rise to real and virtual images of real objects at visible wavelengths. Most importantly, we found that the nonlinear image evolution is not governed by the traditional lens equation but by a modified version of it.

O 77.24 Wed 18:15 Poster A

Ultrathin metasurfaces for nonlinear optical image encoding — •Felicitas Walter[1], Guixin Li[2], and Thomas Zentgraf[1] — [1]Department of Physics, University of Paderborn, D-33098, Germany — [2]Department of Materials Science and Engineering, Southern University of Science and Technology, Shenzhen, 518055, China

In this project we demonstrate that an ultrathin nonlinear photonic metasurface, consisting of meta-atoms with three-fold rotational symmetry, can be used to hide optical images under illumination with a fundamental wave. However, the hidden image can be read out from second harmonic generation (SHG) waves. This is achieved by controlling the destructive and constructive interferences of SHG waves from two neighboring meta-atoms. In addition, we apply this concept to obtain grey-scale SHG imaging. Nonlinear metasurfaces based on space variant optical interference open new avenues for multi-level image encryption, anti-counterfeiting and background free image reconstruction.

O 77.25 Wed 18:15 Poster A

On the resonances of an optical microcavity based on a hyperbolic metamaterial — •Thomas Kiel[1], Evgenij Travkin[1], Sergey Sadofev[1], Oliver Benson[1], Sascha Kalusniak[1], and Kurt Busch[1,2] — [1]Humboldt-Universität zu Berlin, Institut für Physik, Newtonstr. 15, 12489 Berlin — [2]Max-Born-Institut, Max-Born-Str. 2A, 12489 Berlin

Metamaterials provide a rich variety of physical effects such as phase and group velocity control and negative refraction. Here, we present unusual resonance effects of a microcavity filled with a hyperbolic metamaterial (HMM). The HMM is based on pairs of stacked layers of epitaxially grown ZnO / ZnO:Ga.

We compare the experimental reflection spectra with numerical computations using the scattering-matrix algorithm. With the computation of the resonance states, a.k.a. quasi-normal modes, we gain a deeper understanding in the emergence of the cavities' resonances. We identify the different modes supported by computing their field distributions. Furthermore we can map out the modes' dispersion relation in good agreement with the experimental angular-resolved spectra. The tuning of the layer thicknesses and doping level of the HMM core allows us to tailor the modes of the system.

O 77.26 Wed 18:15 Poster A

Towards Superconducting Niobium Plasmonics for Light Detection — •Ahmed Farag, Shahin Bagheri, and Harald Giessen — 4th Physics Institute and Research Center SCOPE, University of Stuttgart, D-70550 Stuttgart, Germany

Nowadays with the fast developments in quantum computing and single photon emitters,avalanche photodiodes as photon detectors are replaced by the superconducting nanowire single-photon detectors. These detectors have a large active area, enabling high absorption efficiency but unfortunately, they slow down the detector response and increase the recovery time. To overcome this problem, plasmonic concepts can be combined with superconducting photon detectors to decrease the active area of the detector while maintaining the high absorption efficiency. Niobium is one of the most promising materials for such purpose since it has a reasonable transition temperature, low kinetic inductance, as well as promising plasmonic properties. Here, we study the optical properties of niobium and niobium nitride upon different sputtering conditions for plasmonics application. Two different nanofabrication techniques are used, namely, electron beam lithography for preparation of precise and complex designs and laser interference lithography for large-area nanostructures. Our results show tunability of the plasmon resonance and consequently the corresponding absorptions in the near infrared range. The absorption can be enhanced further to near unity using a perfect absorber design. The investigations into the plasmonic properties of superconducting niobium opens a gate for future single photon applications.