O 34: Poster Session I (Graphene; Plasmonics and nanooptics; Coherence and coherent control in nanophotonics and plasmonics)

Time: Tuesday 18:15–21:45 Location: Poster E

O 34.1 Tue 18:15 Poster E

Oxidation of monovacancies in graphene by oxygen molecules — •Udo Schwingenschlögl, Thaneshwor Kaloni, and Yingchun Cheng — KAUST, PSE Division, 23955-6900 Thuwal, Kingdom of Saudi Arabia

We study the local magnetic moments develop at monovacancies in graphene due to the presence of dangling carbon bonds. These moments remain intact when an oxygen molecule is adsorbed such that the dangling bonds are not fully saturated. We obtain values of 1.35 and 1.86 μ_B for the magnetic moments of monovacancies and oxidized monovacancies, respectively. A transition from semimetallic to semiconducting behavior appears if at least one C–O–C bridge is present, whereas the formation of C=O groups makes the system metallic. Our results explain the experimentally observed behavior of graphene under exposure to an oxygen plasma.

Reference: J. Mater. Chem. **21**, 18284 (2011).

O 34.2 Tue 18:15 Poster E

Growth of epitaxial graphene on Rh(111) — •Karin Gotterbarm, Christian Papp, Oliver Höfert, Wei Zhao, and Hans-Peter Steinrück — Lehrstuhl für Physikalische Chemie II, Universität Erlangen-Nürnberg, Egerlandstr. 3, 91058 Erlangen

Epitaxial graphene was grown on a Rh(111) single crystal surface by chemical vapor deposition of propylene at elevated temperatures. The growth process was observed by fast XPS performed at the synchrotron facility BESSY II. The quality of the produced graphene sheets was checked by LEED. Different preparation parameters such as propylene pressure and preparation temperature were varied in order to investigate the influence of these parameters on corrugation and regularity of the produced graphene sheet. Additionally we explored the thermal stability of the produced graphene layers as well as the possibility to oxidise these layers. The lattice mismatch of graphene on the Rh(111) surface induces corrugation of the graphene sheet leading to two separated signals in the C 1s region.* The binding energy separation of the two species becomes more distinct at lower temperatures and varies depending on the preparation parameters mentioned above.

Support is acknowledged from the BMBF (05 ES3XBA/5) and the Cluster of Excellence "Engineering of Advanced Materials".

* A. B. Preobrajenski, May Ling Ng, A. S. Vinogradov, N. Mårtensson, Phys. Rev. B 78, 2008, 073401.

O 34.3 Tue 18:15 Poster E

Investigation of excitonic Fano resonances in graphene using optical spectroscopy — •Patrick Herlinger[1,2], Daniela Ullrich[1,2], Dong-Hun Chae[1], Harald Giessen[2], Jurgen Smet[1], and Markus Lippitz[1,2] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]4th Physics Institute, University of Stuttgart

Using transmission and reflection spectroscopy we examine the optical response of graphene from the visible to the UV regime. The optical absorbance spectrum shows an asymmetric peak of about 10% at around 4.7 eV. We introduced a Fano model which is in excellent agreement with our experimental data. Our model includes an excitonic state beneath the saddle point M of the band structure [1]. We study the influence of the environment on the excitonic Fano resonance. We compare the optical response of free-standing and supported graphene and investigate the dependence on the ambient conditions.

[1] Chae et al., Nano Lett. 11, 1379 (2011)

O 34.4 Tue 18:15 Poster E

Graphene on mica: corrugation of monolayer and stacking faults within few-layer graphene studied by scanning tunneling microscopy (STM) — •Silke Hattendorf, Alexander Georgi, Viktor Geringer, Marcus Liebmann, and Markus Morgenstern — II. Institute of Physics B and JARA-FIT, RWTH-Aachen

Graphene flakes were prepared on freshly cleaved mica by exfoliation. The topography of mono- and few-layer flakes was studied down to atomic resolution revealing an overall roughness of (61 ± 13) pm on the monolayer, which is a bit more than measured recently with atomic force microscopy (24,1 pm) [2] but flat compared to graphene on silicon dioxide (320 pm) [1]. The corrugations are analyzed in respect to height and correlation length. The latter is determined by analyzing the auto correlation functions. The results are compared to those on silicon dioxide [1] and earlier measurements on a few-layer flake on mica.

On few-layer graphene on mica a large triangular network of partial dislocations separating differently stacked graphene areas was studied. Such networks have been observed before on HOPG [3,4]. Due to differences in the electronic structure of hexagonal and rhombohedral graphite, the differently stacked areas appear to be separated by edges of 1-4 Å height. This apparent height depends on the bias voltage. This dependency is studied by scanning tunneling spectroscopy (STS).

[1] V. Geringer et. al., Phys. Rev. Lett.102, 76102 (2009).
[2] C. Lui et. al., Nature 462, 339 (2009).
[3] S. Amelinckx and P. Delavignette, J. Appl. Phys. 31, 2126 (1960).
[4] S. Snyder et. al., Phys. Rev. B 47, 10823 (1993).

O 34.5 Tue 18:15 Poster E

An electron lens out of strained graphene — Lukas Gerhard[1], Eric Moyen[2], •Timofey Balashov[1], Igor Ozerov[2], Marc Portail[3], Houda Sahaf[2], Laurence Masson[2], Wulf Wulfhekel[1], and Margrit Hanbücken[2] — [1]Physikalisches Institut, Karlsruhe Institute of Technology, Germany — [2]CINaM-CNRS, Aix-Marseille University, Marseille, France — [3]CRHEA-CNRS, Valbonne, France

An epitaxial layer of graphene was grown on a 6H-SiC(0001) crystal, prepatterned with hexagonal nano-holes. The graphene layer covers the surface smoothly, without dislocations or grain boundaries. The necessary elastic deformation of graphene leads to a strain-induced modification of electron group velocity in the graphene layer, and to an increased time-of-flight across the nano-hole. We propose to use this effect to focus two-dimensional electrons in analogy with simple optical lenses.

O 34.6 Tue 18:15 Poster E

Local transport measurements in graphene and graphene nanostructures — •Frederik Edler, Jens Baringhaus, Thomas Langer, Herbert Pfnür, and Christoph Tegenkamp — Institut für Festkörperphysik, Leibniz Universität Hannover, Abteilung Atomare und Molekulare Strukturen, Appelstrasse 2, 30167 Hannover, Germany

Graphene exhibits interesting transport signatures. The non-vanishing conductivity in neutral graphene was believed to be a signature of a ballistic system. However, diffusive transport theory including long range ordered defects reveal similar conductance values. Therefore, the control of the structure is important in order to interpret transport data, affected by in impurities, defects, or finite size effects, correctly. We have studied the morphology and the resistivity of graphene and graphene nanostructures by means of a 4-tip STM SEM system.

Due to inhomogeneous growth and the residual influence of substrate, the sheet resistance for monolayer graphene, grown on SiC(0001) and SiC($000\bar{1}$) substrates, was around 40-50 k$\Omega/\square$. After further graphitization it decreased to 8 k$\Omega/\square$. Graphene bilayers on SiC($000\bar{1}$) reveal values close to those reported for exfoliated graphene. Besides 2d graphene, uniaxial graphene nanoribbon structures (width $\approx$ 100 nm), grown by using appropriate SiC-MESA structures, have been studied. The resistances measured on them were found to be significantly lower and are almost independent on the contact separation, as expected for graphene ribbons with robust edge channels.

O 34.7 Tue 18:15 Poster E

Production of Nitrogen-Doped Graphene via Low Energy Nitrogen Bombardment — •Wei Zhao[1], Olive Höfert[1], Karin Gotterbarm[1], Junfa Zhu[2], Christian Papp[1], and Hans-Peter Steinrück[1] — [1]Lehrstuhl für Physikalische Chemie II, Universität Erlangen-Nürnberg, Egerlandstr. 3, 91058 Erlangen — [2]National Synchrotron Radiation Laboratory, UniVersity of Science and Technology of China, Hefei 230029, Peoples Republic of China

Tailoring the electronic structure of graphene by chemical modification of graphene represents a crucial route to the synthesis of a new class of

semiconductor materials. The covalent introduction of nitrogen might pave a way to use tailored graphene in electronic devices. Herein, we report a simple procedure to insert nitrogen atoms into graphene by low energy nitrogen bombardment, forming nitrogen-doped graphene. Applying high resolution X-ray photoelectron spectroscopy, different carbon-nitrogen species in the nitrogen-doped graphene sheet are identified. Additionally, the distribution of nitrogen in its doping sites and the doping level becomes available. The doping level and doping sites of nitrogen-doped graphene can be varied by changing the nitrogen bombardment energies and times.

Support is acknowledged from the BMBF (05 ES3XBA/5) and the Cluster of Excellence "Engineering of Advanced Materials".

O 34.8 Tue 18:15 Poster E

Graphene as a supporting layer for nanoparticles — •Torsten Veltum, Wolfgang Rosellen, Hendrik Bettermann, and Mathias Getzlaff — Institute of Applied Physics, University Duesseldorf

In the past few years graphene has gained the attention of scientists due to its unique mechanical and electrical properties. On the other hand, fabrication and deposition of nanoparticles on a substrate is of great interest for studies of, e.g. model catalysts. In this study we want to get a better understanding of the interaction between the nanoparticles and graphene substrate.

A thin Ni(111) film is prepared by electron beam evaporation on a W(110) crystal under ultra-high vacuum conditions. To achieve a structurally ordered monolayer graphene on the ferromagnetic substrate we use chemical vapor deposition with propylene. The structure of the thin film system is characterized in-situ by means of scanning tunneling microscopy (STM), low energy electron diffraction (LEED) and auger electron spectroscopy (AES).

The well-characterized FeCo nanoparticles are produced by a continuously working arc cluster ion source (ACIS), mass-selected by an electrostatic quadrupole ($\Delta m/m = 10\%$) and subsequently deposited on the single-layer graphene under softlanding conditions. The structural analysis of the nanoparticles is carried out by STM.

O 34.9 Tue 18:15 Poster E

Strain Modulation of Graphene Nanoribbons — •Yingchun Cheng[1], Hongtao Wang[2], Zhiyong Zhu[1], Xixiang Zhang[3], and Udo Schwingenschlogl[1] — [1]PSE Division, KAUST, Thuwal 23955-6900, Kingdom of Saudi Arabia — [2]Institute of Applied Mechanics, Zhejiang University, Hangzhou 310027, China — [3]Advanced Nanofabrication, Imaging and Characterization Core Lab, KAUST, Thuwal 23955-6900, Kingdom of Saudi Arabia

The edge structure and width of graphene nanoribbons (GNRs) are crucial factors determining the electronic structure. A combination of experiment and first-principles calculations allows us to study the mechanism of transformation from hexagon-hexagon (66) to pentagon-heptagon (57) configuration. Thin GNRs (< 2 nm) are fabricated by bombardment of a graphene sheet with high-energetic Au clusters. The edges of the GNRs are modified *in-situ* by electron irradiation. Tensile strain along the edge decreases the transformation energy barrier from the 66 to the 57-GNR. A thin 66-GNR is antiferromagnetic with direct band gap, a 57-GNR turns out to be an indirect semiconductor, and a GNR transformed on only one edge is ferromagnetic. We propose that strain can be an effective method to tune the edge (and electronic) structure of thin GNRs for graphene based electronics.

O 34.10 Tue 18:15 Poster E

Strain Modulation of Graphene Nanoribbons — •Yingchun Cheng[1], Hongtao Wang[2], Zhiyong Zhu[1], Xixiang Zhang[3], and Udo Schwingenschlogl[1] — [1]PSE Division, KAUST, Thuwal 23955-6900, Kingdom of Saudi Arabia — [2]Institute of Applied Mechanics, Zhejiang University, Hangzhou 310027, China — [3]Advanced Nanofabrication, Imaging and Characterization Core Lab, KAUST, Thuwal 23955-6900, Kingdom of Saudi Arabia

The edge structure and width of graphene nanoribbons (GNRs) are crucial factors determining the electronic structure. A combination of experiment and first-principles calculations allows us to study the mechanism of transformation from hexagon-hexagon (66) to pentagon-heptagon (57) configuration. Thin GNRs (< 2 nm) are fabricated by bombardment of a graphene sheet with high-energetic Au clusters. The edges of the GNRs are modified *in-situ* by electron irradiation. Tensile strain along the edge decreases the transformation energy barrier from the 66 to the 57-GNR. A thin 66-GNR is antiferromagnetic with direct band gap, a 57-GNR turns out to be an indirect semiconductor, and a GNR transformed on only one edge is ferromagnetic. We propose that strain can be an effective method to tune the edge (and electronic) structure of thin GNRs for graphene based electronics.

O 34.11 Tue 18:15 Poster E

Non-linear optics in graphene — •Evgeny Bobkin, Torben Winzer, Ermin Malic, and Andreas Knorr — Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, 10623 Berlin, Germany

We present a microscopic study on non-linear optics in graphene including the investigation of Rabi oscillations, adiabatic following, and detuning effects. Our approach is based on the density matrix formalism, which allows a straight-forward inclusion of many-body interactions, such as excitonic effects. By solving the microscopic graphene Bloch equations we gain a time- and momentum-resolved access to the non-linear dynamics of the charge carriers and the coherence [1]. We investigate the appearance of Rabi oscillations as a function of time and pump fluence for different excitation regimes. Furthermore, we compare the free-particle and the excitonic picture to extract the influence of the Coulomb interaction.

[1] Ermin Malic, Torben Winzer, Evgeny Bobkin and Andreas Knorr, "Microscopic theory of excitonic absorption and ultrafast many-particle kinetics in graphene", Phys. Rev. B 84, 205406 (2011)

O 34.12 Tue 18:15 Poster E

Local anodic oxidation of graphene by scanning force microscopy — •Marcus Liebmann, Theresa Hecking, Alexander Nent, Lena Jung, Jonas van Bebber, Jens Kellner, Lisa Felker, Silke Hattendorf, Nils Freitag, and Markus Morgenstern — II. Phys. Inst. B, RWTH Aachen University and JARA-FIT, Germany

For structuring graphene flakes exfoliated on a substrate, local anodic oxidation (LAO) is an interesting tool which avoids the contamination of large parts of the flake during processing using conventional lithography. Being well-established for semiconductor nanostructures [1], this technique has also been applied to graphene more recently [2]. It makes use of the oxidation of the surface at the contact area between a sample and a scanning tip of an atomic force microscope (AFM) when a bias voltage is applied under ambient conditions.

Graphene flakes exfoliated on SiO_2 and contacted by Indium soldering are modified by LAO. We observe two main processes: oxidation and cutting, depending on parameters like voltage, load force, tip velocity, and humidity. Appropriate sets of parameters are investigated and first nanostructures are tested. Line widths of 40 nm could be achieved. Conductivity measurements indicate that cut lines are insulating and oxidized structures show sheet resistances of at least 300 GΩ. Graphene samples have also been prepared on BN and the morphology has been analyzed by AFM.

[1] R. Held et al., Appl. Phys. Lett. 71, 2689 (1997).
[2] A. J. M. Giesbers et al., Solid State Commun. 147, 366 (2008).

O 34.13 Tue 18:15 Poster E

Mechanical exfoliation of epitaxial graphene on Ir(111) enabled by Br_2 intercalation — •Charlotte Herbig[1], Markus Kaiser[2], Nedjma Bendiab[3], Johann Coraux[3], Klaus Meerholz[2], Thomas Michely[1], and Carsten Busse[1] — [1]II. Physikalisches Institut, Universität zu Köln, Germany — [2]Institut für Physikalische Chemie, Universität zu Köln, Germany — [3]Institut Néel, CNRS-UJF, France

For a technological use of graphene, it is desirable to grow it on a large scale with a reproducible high quality. The best quality up to date is achieved by growth on metal substrates. Especially on Ir(111), strictly monoatomic graphene sheets of well defined orientation and macroscopic extension are achieved [1]. For application graphene on metals is non-suitable. Therefore, a transfer is necessary. Here, we present a method for a dry transfer of graphene grown on Ir(111).
First, the epitaxially grown graphene layer was investigated by LEED and STM. Afterwards, graphene was intercalated by Br_2 and examined by SEM. The transfer process was conducted by attaching adhesive tapes as supporting material and subsequent removal. Finally, the surface was analyzed by SEM. Raman spectroscopy was carried out to prove the transfer of graphene onto the adhesive tapes.
[1] R. van Gastel et al., Appl. Phys. Lett. 95 (2009) 121901

O 34.14 Tue 18:15 Poster E

Microscopic derivation of screened Graphene-Bloch equations — •Eike Verdenhalven[1], Ermin Malic[1], Rolf Binder[2], and Andreas Knorr[1] — [1]Institut für Theoretische Physik, Technis-

che Universität Berlin, Germany — [2]College of Optical Sciences and Department of Physics, University of Arizona, Tucson, USA

The Coulomb interaction is known to be very strong in low-dimensional carbon-nanostructures, such as carbon nanotubes and graphene. Earlier calculations and experiments have revealed that excitonic effects significantly change the optical properties even of metallic nanotubes and graphene [1, 2]. However many-particle interaction also leads to the reduction of the Coulomb interaction strength by introducing an internal screening. In this work, we present a fully microscopic derivation of the dielectric function in the static limit. Within a density-matrix formalism we derive screened graphene-Bloch equations and a screened microscopic Boltzmann equation in second order Born-Markov approximation. We calculate the dielectric function in dependence of the momentum transfer along different directions in the Brillouin zone of graphene, showing its highest value of about 4.7 for small momentum transfer.

[1] E. Malić, T. Winzer, E. Bobkin, and A. Knorr, Phys. Rev. B 84, 205406, (2011)

[2] E. Malić, J. Maultzsch, S. Reich, and A. Knorr, Phys. Rev. B 82, 035433 (2010)

O 34.15 Tue 18:15 Poster E

Mechanical exfoliation of graphene in UHV — •Gerrit Begall, Oliver Ochedowski, and Marika Schleberger — Universität Duisburg-Essen, Duisburg, Germany

Our new approach to graphene preparation is mechanical exfoliation under UHV-conditions.

There are typically two ways of preparing graphene on an arbitrary substrate: The mechanical exfoliation (known as the scotch tape method) and the transfer of CVD-graphene (graphene grown on Ni by chemical vapor deposition), using a polymer which is dissolved later.

Both techniques are far from being perfect, regarding cleanliness of the samples and graphene properties. Scotch tapes, used in the mechanical exfoliation method, leave adhesives and there is usually water intercalated inbetween substrate and graphene. The quality of CVD-graphene is inferior to the quality of exfoliated graphene regarding its physical properties, since it consists of small domains. The chemicals involved in the transfer (acetone, PMMA) can be problematic as well.

With the possibilities of an UHV-system, we can prepare atomically clean substrates by sputtering and heating. After this cleaning, a graphenium-flake or a HOPG-crystal is pressed onto the sample. We plan to prepare graphene on Ni, Si (7x7) and SiO_2 surfaces. The results will be compared to classically prepared graphene.

O 34.16 Tue 18:15 Poster E

Theoretical modelling and interpretation of the C $1s \rightarrow \pi^*, \sigma^*$ X-ray absorption spectra of $H_2O(NH_3)$/graphene — •Elena Voloshina[1], Roman Ovcharenko[1,2], Aleksander Shulakov[2], Beate Paulus[1], and Yuriy Dedkov[3] — [1]Physikalische und Theoretische Chemie, Freie Universität Berlin, Germany — [2]V. A. Fock Institute of Physics, Saint-Petersburg State University, Russia — [3]SPECS Surface Nano Analysis GmbH, Germany

Recently, adsorption of polar molecules on graphene/Ni(111) was investigated by means of angle-resolved photoelectron spectroscopy (ARPES) and X-ray absorption spectroscopy (XAS) [1]. It was found, that adsorption of H_2O and NH_3 leads to the noticeable modification of the XAS C K-edge spectra indicating the orbital mixing of the valence band states of graphene and adsorbates. Further analysis of the obtained results allows assuming the site-selective adsorption for the two studied adsorbates. However, neither position nor orientation of the adsorbate were determined. In order to clarify these aspects, we performed the first-principles electronic structure calculations on the H_2O/graphene and NH_3/graphene systems as well as modelling the C K-edge XAS spectra of these systems. The dynamical core-hole screening effects in the XAS spectra were taken into account via the multiband Mahan-Nozieres-De Dominicis (MND) theory [2]. The presented theoretical results are compared to available previously published theoretical data as well as experimental observations.

[1] S. Böttcher *et al.* Nanoscale Res. Lett. **6**, 214 (2011).

[2] O. Wessely *et al.* Phys. Rev. B **73**, 075402 (2006).

O 34.17 Tue 18:15 Poster E

Quasi-free standing trilayer epitaxial graphene on SiC(0001) — •Stiven Forti[1], Camilla Coletti[2], Konstantin V. Emtsev[1], Alexei Zakharov[3], Kevin Daniels[4], Biplob Daas[4], M.V.S. Chandrashekhar[4], and Ulrich Starke[1] — [1]Max Planck Institute for Solid State Research, Heisebergstr. 1, 70569 Stuttgart, Germany — [2]Center for Nanotechnology Innovation @ NEST, Istituto Italiano di Tecnologia, Piazza San Silvestro 12, 56127 Pisa, Italy — [3]Max Lab, Lund University, Box 118, Lund, S-22100, Sweden — [4]University of South Carolina, 301 S. Main St, Columbia, SC 29208, USA

The control of the thermal decomposition of the 6H-SiC(0001) surface to grow a homogeneous coverage of epitaxial few-layers graphene remains not easily achievable in the experiments. In the present work, we report on high resolution ARPES data, showing the electronic band structure of quasi-free standing trilayer epitaxial graphene. The system is characterized in different doping conditions, from p-type to charge neutrality. LEEM data provide evidence that the number of graphene layers is homogeneous over the surface up to a several micron scale. The question of different stacking sequences will be addressed with the aid of theoretical calculations to fit the experimental band structures.

O 34.18 Tue 18:15 Poster E

Excited electron dynamics in Au-intercalated Graphene on Ni(111) — •Carsten Winter[1], Thorben Haarlammert[1], Luca Bignardi[2], Petra Rudolf[2], and Helmut Zacharias[1] — [1]Physikalisches Institut, Westfälische Wilhelms-Universität Münster — [2]Zernike Institute for advancd materials, University of Groningen

Theoretical calculations predict an initial ultrafast relaxation of hot electrons accompanied by a population of optical phonons, which decays on a picosecond time scale[1]. We present an experimental set-up suited to measure the lifetime of excited electrons and their relaxation dynamics in Graphene via time-resolved two-photon photoemission. The set-up utilizes an amplified Ti:sapphire laser to generate intense femtosecond pulses with high repetition rates. Through frequency conversion by High Harmonic Generation coherent radiation at 39 eV photon energy is generated and subsequently used as the probe pulse in two-photon photoemssion. The fundamental radiation of the Ti:Sa laser is used to excite the carriers.

Graphene was produced by decomposition of ethylene on a Ni(111) substrate. The Laser-Assisted Photoelectric Effect (LAPE) was utilized to determine the XUV pulse duration to 28 fs. First experiments reveal a Ni(111) nonthermal electron lifetime of less than 20 fs. Additional measurements on Au-intercalated Graphene and Graphene on SiC will be presented.

[1]T. Elsaesser et al., Phys. Rev. Lett. 66 (1991) 1757

O 34.19 Tue 18:15 Poster E

Water adsorption on heteroepitaxial graphene — •Janine Scherer, Samir Mammadov, Thomas Seyller, and Sabine Maier — Department für Physik, Universität Erlangen-Nürnberg

Graphene devices operated in ambient conditions are exposed to a variety of molecules. Here, we focus in particular on water, which can act as dopant and might alter the electronic properties of such devices. We study epitaxial graphene grown on 6H-SiC(0001) upon water adsorption using high resolution scanning tunneling microscopy operated in ultrahigh vacuum conditions at low temperature. We will discuss the adsorption structures of water on clean graphene surfaces with respect to the number of graphene layers. While water forms clusters on the interface layer, it leads to significant topographical changes for single and multiple graphene layers. We observe that graphene is split into small flakes in the vicinity of step edges, which is unfavorable for technological applications.

O 34.20 Tue 18:15 Poster E

Interaction of manganese and nickel with epitaxial graphene on Ir(111) — •Hendrik Vita, Stefan Böttcher, Martin Weser, Yuriy Dedkov, and Karsten Horn — Fritz-Haber-Institut der Max-Planck-Gesellschaft, 14195 Berlin, Germany

In view of an application as spin filter, the interaction of graphene with magnetic materials is interesting. Here we report on a LEED as well as core and valence level photoemission study of the interaction of manganese and nickel adlayers and intercalated layers with graphene grown epitaxially on Ir(111). We examine the doping effect of the adlayers and intercalates through a shift of the Dirac cone to higher binding energies. In a second step, the growth of alloys films of Mn and Ni by stepwise deposition and annealing is examined. We compare our data to Al and Fe intercalated layers in graphene grown on Ni(111).

O 34.21 Tue 18:15 Poster E

Interaction of Water Molecules with Graphene — •Sebastian Standop, Thomas Michely, and Carsten Busse — II. Physikalisches Institut, Universität zu Köln

Graphene is a promising candidate as an electrode material in future electronics including ultracapacitors [1] and dye sensitized solar cells [2]. With the potential of graphene to be used in electrochemical applications it is of great interest to understand in detail structure as well as adsorption kinetics and energetics of water on graphene. Therefore we dosed water onto a graphene covered Ir(111) surface and performed both scanning tunneling microscopy (STM) and thermal desorption spectroscopy (TDS). For low coverages adsorbed at 20 K the water layer shows zero order desorption with an high temperature shoulder increasing with coverage, eventually leading to a complete suppression of the initial peak in favor of the high temperature structure. When elevating the adsorption temperature above 100 K the formation of the second structure is preferred over the low coverage phase indicating its metastable character. We presume that this transition corresponds to a reduced number of dangling bonds within the water layer which is due to the hydrophobicity of the graphene substrate [3]. Our real space analysis corroborates these findings by showing heavy manipulation of the low coverage phase even at 20 K. When increasing the coverage the water molecules organize in extended islands aligned to the inherent moiré supercell of epitaxially grown graphene. [1] C. Liu *et al.*, Nano Lett. 10, 4863 (2010); [2] X. Wang *et al.*, Nano Lett. 8, 323 (2008); [3] G. A. Kimmel *et al.*, J. Am. Chem. Soc. 131, 12838 (2009)

O 34.22 Tue 18:15 Poster E

Intercalation of Cs through wrinkles of epitaxial graphene — Marin Petrović[1], Iva Šrut[1], Ivo Pletikosić[1], Petar Pervan[1], Milorad Milun[1], Sven Runte[2], Carsten Busse[2], Thomas Michely[2], Jurek Sadowski[3], Tonica Valla[3], and •Marko Kralj[1] — [1]Institut za fiziku, Zagreb — [2]II. Physikalisches Institut, Köln — [3]Brookhaven National Lab, New York

Interclation of alkali atoms is a straightforward route for the chemical doping of epitaxial graphene (G). This has been demonstrated for graphene on SiC [1] as well as for graphene on metals [2], where dopings/shifts of the Dirac cone at the K-point near the Fermi level have been followed by angle-resolved photoemission spectroscopy (ARPES). However, ARPES is area-averaging technique which does not provide a clear picture on the process of the penetration of alkali atoms to a position between graphene layer and its support. Our ARPES studies for intercalation of Li, Na, K, and Cs to G/Ir(111) have indicated that dynamics of alkali intercalation depend on the size of the alkali atom and we have focused to the intercalation of large alkali atom, Cs. By the combination of ARPES, scanning tunneling microscopy and low-energy electron microscopy we reveal two different doping effects from Cs on top and intercalated compact layer which is formed by a diffusion of Cs atoms through wrinkles network of graphene.

[1] J. L. McChesney, et al., Phys. Rev. Lett. 104, 136803 (2010).
[2] M. Bianchi, et al., Phys. Rev. B 81, 041403(R) (2010).

O 34.23 Tue 18:15 Poster E

Raman spectrum of the $(6\sqrt{3} \times 6\sqrt{3})R30^\circ$ reconstructed surface of 6H-SiC(0001) — •Felix Fromm[1], Martin Hundhausen[1], Myriano Henriques de Oliveira Jr.[2], Marcelo Lopes[2], Henning Riechert[2], and Thomas Seyller[1] — [1]Universität Erlangen-Nürnberg, Lehrstuhl für Technische Physik, 91058 Erlangen — [2]Paul-Drude-Institut für Festkörperelektronik, 10117 Berlin

The epitaxial growth of graphene on silicon carbide (SiC) by thermal sublimation of silicon in an argon atmosphere is a prominent method to produce high quality graphene layers. There are two approaches to obtain graphene on SiC: As an initial step of graphene formation a $(6\sqrt{3} \times 6\sqrt{3})R30^\circ$ reconstructed overlayer of carbon, the so-called buffer layer (BL) is formed. Further graphitisation converts the BL to graphene and forms a new BL underneath (MLG). Another path is the conversion of the BL to graphene via intercalation of hydrogen. This results in quasi-free-standing graphene on hydrogen saturated SiC (QFMLG). In this work we analysed Raman spectra of QFMLG and MLG. Since graphene is highly transparent the substrate underneath the garphene contributes to the Raman spectrum. Therfore a SiC Raman spectrum has to be subtracted to obtain the Raman signal of the graphene layers. Whereas the Raman spectrum of QFMLG shows symmetric D and G lines, the spectrum of MLG shows additional broad features in the D and G range. We assign these broad contributions to the Raman spectrum of the BL.

O 34.24 Tue 18:15 Poster E

Giant Rashba splitting in graphene/SiC(0001) after Au intercalation — •Dmitry Marchenko[1], A. Varykhalov[1], J. Sánchez-Barriga[1], M. R. Scholz[1], Th. Seyller[2], and O. Rader[1] — [1]Helmholtz-Zentrum Berlin — [2]Universität Erlangen

We have recently demonstrated a giant spin-orbit splitting in graphene/Ni(111) after intercalation of a Au monolayer. The spin-orbit splitting is by 4 orders of magnitude larger than the intrinsic splitting of graphene. The intercalation approach works also for graphene on SiC(0001) which is one of the most popular substrates for high quality graphene growth. We show that in graphene/SiC the spin splitting of the Dirac-cone is zero, but intercalation of a gold layer under the graphene dramatically increases the splitting up to 120 meV.

O 34.25 Tue 18:15 Poster E

Characterization of functional plasmonic elements: a far-field approach — •Christian Rewitz[1], Thomas Keitzl[1], Philip Tuchscherer[1], Jer-Shing Huang[2], Peter Geisler[3], Gary Razinskas[3], Bert Hecht[3,4], and Tobias Brixner[1,4] — [1]Institut für Physikalische und Theoretische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [2]Department of Chemistry, National Tsing Hua University, Hsinchu 30013, Taiwan — [3]Nano-Optics and Biophotonics Group, Experimentelle Physik 5, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [4]Röntgen Center for Complex Material Systems (RCCM), Am Hubland, 97074 Würzburg, Germany

Plasmonic modes supported by noble-metal nanostructures offer strong subwavelength confinement and promise the realization of nanometer-scale integrated optical circuits with well-defined functionality. In view of applications in the field of optical communication the dispersion and group velocity of plasmon propagation are of high interest. Here, we present a microscope setup that employs a far-field technique to measure the spectral and spatial transfer functions of plasmonic elements thus enabling us to determine the dispersion and group velocity of plasmon propagation. For the exact determination of the plasmon group velocity, i.e., the speed of ultrashort propagating pulses representing bits of information, a detailed knowledge of the setup transfer function is needed, which we provide here. The setup inherent time delay of signals due to different path lengths is measured with 1 fs accuracy and is used to obtain corrected results for plasmon group velocities.

O 34.26 Tue 18:15 Poster E

Photochemical metal deposition in nanoporous aluminum oxide matrices — •Julia Katzmann and Thomas Haertling — Fraunhofer Institute for Nondestructive Testing, Maria-Reiche-Str. 2, 01109 Dresden, Germany

Well-ordered arrays of metal nanorods show highly interesting optical properties which make them promising structures for sensor applications [1]. Such arrays can be fabricated via template-based methods at low cost and on large areas.

We report on a proof-of-concept investigation which demonstrates the targeted photochemical deposition [2] of gold into the pores of anodized aluminum oxide (AAO). We exploit a thin layer of gold sputtered onto one side of the AAO membrane as a seed layer for the photochemical process. A solution of $HAuCl_4$ is applied onto the other side of the membrane. Upon UV light irradiation, nanorods grow within the oxide matrix without the need of an electrical contact. The optical properties of the gold-filled matrices, i.e., the excitation of plasmons in the nanorods were measured by means of optical transmission spectroscopy, while the rod length was determined by scanning electron microscopy. We observe a spectral blue shift of the transversal plasmon resonance with increasing rod length. This finding is correlated with different fabrication parameters to obtain a detailed understanding of the photochemical growth process.

[1] A.V. Kabashin et.al, Nature Materials 8, 857 (2009)
[2] T. Haertling et.al, Optics Express 16, 12362 (2008)

O 34.27 Tue 18:15 Poster E

Mapping of gold nanostructure-induced near-field enhancement — •Oksana Kostiuchenko[1,2], Jacek Fiutowski[2], Christian Maibohm[2], Jakob Kjelstrup-Hansen[2], Horst-Günter Rubahn[2], and Heinz Sturm[1] — [1]BAM - Div. Nanotribol. & Nanostruct., Berlin — [2]Univ. of Southern Denmark, Mads Clausen Inst., NanoSYD, 6400 Sønderborg, DK

Sub-diffraction spatially resolved, quantitative mapping of strongly localized field intensity enhancements on gold nanosquares and nanotriangles via laser scanning femtosecond (fs) ablation of polymer thin films and via second harmonic generation (SHG) is reported. Using electron beam lithography, periodical patterns of gold squares and triangles on gold thin films are fabricated. Subsequently, poly(methyl

methacrylate) (PMMA) is spin coated on top of such nanostructures. Illumination by a scanning fs laser beam induces an electromagnetic surface field, which is locally enhanced at the edges of the nanostructures and - under appropriate excitation wavelength conditions - also between the structures due to surface plasmon excitation. This enhancement lowers the threshold for nonlinear optical effects such as surface second harmonic generation or deformation and ablation of the polymer coating. The scanning laser beam thus results in a two-dimensional map of near field enhancement, imprinted into the polymer and directly seen via SHG. A variation of the polymer film thickness enables one to discriminate between edge and surface plasmon enhancement effects.

O 34.28 Tue 18:15 Poster E

Plasmons in Ag-Nanowires Grown on Si (557) — •Yu Zhang, Ulrich Krieg, Christian Brand, Herbert Pfnür, and Christoph Tegenkamp — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany

We present electron energy loss spectroscopy data of wire like Ag-structures grown via self assembly of on vicinal Si(557) at a coverage of 0.3 monolayers.

Using an instrument with both high energy and high momentum resolution (ELS-LEED) we observed a linearly dispersing plasmon loss parallel to the step-edges and a plasmon loss without dispersion in perpendicular direction.

Spot profile analysis LEED (SPA-LEED) and STM measurements show that the step-structure remains unchanged and the step-edges are still undecorated after the evaporation and annealing process. Both results are strong indications for well separated nanowires with a defined width resulting in a confinement of the plasmon to the individual nanowire.

Further effects of finite wire width and of residual coupling between the wires are discussed.

O 34.29 Tue 18:15 Poster E

Investigation of Si/chalcogenide hybrid slot waveguides — •Peter Nolte, Christian Bohley, and Jörg Schilling — Martin-Luther-Universität Halle-Wittenberg, ZIK SiLi-nano, Halle, Germany

In the last years great efforts lead to a strong miniaturization of optical components, as several devices were realized on the silicon-on-insulator (SOI) platform which is to CMOS technology. The very high refractive index contrast between the Si core, oxide cladding and air, leads to a high confinement of light inside a waveguide. However, for many applications active devices exhibiting a nonlinear optical behavior are needed. One possible way to boost the nonlinear optical properties in integrated optics is the functionalization of SOI-structures with chalcogenide glasses. These glasses (e.g. As_2S_3) exhibit a nonlinear figure of merit of about $\mathrm{Re}(\chi^{(3)})/\mathrm{Im}(\chi^{(3)}) = 10$ in the near infrared. We present slotted SOI-waveguides which have been clad and infiltrated by chalcogenide glasses. The linear optical properties of the clad waveguides were investigated using a fiber coupled laser setup, tuned from 1490 nm to 1640 nm with 1 pm steps. The nonlinear properties have been studied by means of degenerate four wave mixing. Here, two laser beams with frequencies ω_1 and ω_2 interact with each other through the 3rd order nonlinear susceptibility of the waveguides. Thus two new beams formed. From the conversion efficiency and its intensity dependence the averaged 3rd order nonlinear susceptibility $\chi^{(3)}$ for the hybrid waveguide device is determined. We demonstrate how hybrid silicon/As_2S_3 waveguides can perform nonlinear frequency conversion via four wave mixing extending the functionality on integrated SOI photonics.

O 34.30 Tue 18:15 Poster E

Optical fiber sensor with concentric circular gold grating sensitive to change of ambient refractive index — •Sabrina Darmawi[1], Shengfei Feng[2], Torsten Henning[1], Xingping Zhang[2], and Peter J. Klar[1] — [1]I. Physikalisches Institut, Justus-Liebig-Universität, Heinrich-Buff-Ring 16, 35392 Gießen — [2]College of Apllied Sciences, Beijing University of Technology, Beijing 100124

Metallic nanostructures on top of the end facet of an optical fiber can be employed as probes or sensors. Due to their flexibility, durability and large aspect ratio, optical fibers are well-suited for remote sensing. We present a polarization-independent optical sensor consisting of a concentric gold ring grating with a period of 900 nm transferred onto the end facet of an optical fiber. The sensing function of the device is realized by sending white light through the unstructured end and collecting the reflected response signal. A distinct peak due to the Rayleigh anomaly of the gold ring grating is observed in the reflection sprectrum. We show that this peak is sensitive to the change in the environmental refractive index of the end facet of the fiber.

O 34.31 Tue 18:15 Poster E

Multi-wavelength superlensing with layered phonon-resonant dielectric — •Peining Li and Thomas Taubner — I. Institute of Physics (IA), RWTH Aachen University, Sommerfeldstraße 14, 52074 Aachen, Germany

A superlens is a very promising device to overcome the diffraction limit and resolve subwavelength features [1]. However, the practical application of the superlens is limited by its narrow bandwidth since a superlensing condition should be met. For dispersive materials, this condition limits operation to a very small wavelength range for each material system. For example, the superlensing condition for the silicon carbide (SiC) case is met at a wavelength of around 11 μm [2]. Therefore, in order to cover a relatively wide wavelength range, different superlenses should be used [3].

Here, we theoretically propose a possibility of employing a multilayered polar-dielectric system to achieve sub-diffraction limited imaging at different wavelengths. Our theory and simulation results show that this multilayered lens can fulfill the superlensing condition at multiple different wavelengths simultaneously due to the phonon resonances of polar dielectrics, and the number of superlensing wavelengths of the lens can be easily tuned by controlling the number of polar dielectrics. Ideally, by suitably choosing the polar dielectrics, the wavelength range of our lens can cover from infrared to THz frequencies.

O 34.32 Tue 18:15 Poster E

Comparative study of localized surface plasmons in gold ring structures performed by SNOM and PEEM. — •Cristian Gonzalez, Daniela Bayer, Pascal Melchior, Alexander Fischer, Christian Schneider, Bernhard Schaaf, Egbert Oesterschulze, and Martin Aeschlimann — University of Kaiserslautern, Department of Physics, 67663 Kaiserslautern, Germany

We will present a first comparative study on plasmonic nanostructures performed by SNOM (Scanning Near-field Optical Microscopy) and PEEM (Photo-Electron Emission Microscopy). Our new PEEM setup allows measurements under normal and 65° incidence of the laser beam. Hence, we are able to compare directly local near field enhancement in the vicinity of nanostructures obtained by both techniques, PEEM and SNOM under the same geometrical conditions.

With these two complementary microscopy techniques, we have the possibility to address both plasmonic damping channels, the radiative channel by SNOM and the non-radiative channel (electron-hole pair creation) by PEEM. In our first studies we focus on Au ring structures and ring segmented arrays made by electron beam lithography deposited on Indium Tin Oxide (ITO). Ring structures are of special interest because of the high tunability of their optical properties. Besides the interest in fundamental physics of the excitation of multipolar modes, they can be implemented in technological applications as, for example, bio-sensors and resonators.

O 34.33 Tue 18:15 Poster E

ToF-PEEM on Metallic Structures using Attosecond XUV Pulses — •Soo Hoon Chew[1,2], Frederik Süssmann[2], Christian Späth[1], Adrian Wirth[2], Alexander Guggenmos[1,2], Jürgen Schmidt[1], Sergey Zherebtsov[2], Kellie Pearce[1], Andreas Oelsner[3], Nils Weber[4], James Kapaldo[2], Alexander Gliserin[1,2], Ferenc Krausz[1,2], Mark Stockman[5], Matthias Kling[4], and Ulf Kleineberg[1] — [1]Department of Physics, Ludwig Maximilian University of Munich, Garching, Germany — [2]Max Planck Institute of Quantum Optics, Garching, Germany — [3]Surface Concept GmbH, Staudingerweg 7, 55128 Mainz, Germany — [4]Focus GmbH, Hünstetten Kasselbach, 65510, Germany — [5]Department of Physics and Astronomy, Georgia State University, Atlanta, Georgia, 30303 USA

We report on the imaging of gold structures by time-of-flight-photoemission electron microscopy (ToF-PEEM) in combination with extreme ultraviolet (XUV) attosecond pulses from a high harmonic generation (HHG) source. Characterization of lithographically fabricated gold structures using these ultrashort XUV pulses by ToF-PEEM shows a spatial resolution of 200 nm. Energy-filtered imaging of the secondary electrons resulting in reduced chromatic aberrations as well as microspectroscopic identification of core and valence band electronic states have been successfully proven. We also find that the fast valence

band electrons are not infuenced by the space charge effects, which is essentially important for attosecond nanoplasmonic field microscopy realization.

O 34.34 Tue 18:15 Poster E

Coherent two-dimensional nanoscopy – insights into an advanced spectroscopic technique — Martin Aeschlimann[1], Tobias Brixner[2], Alexander Fischer[1], •Christian Kramer[2], Pascal Melchior[1], Walter Pfeiffer[3], Christian Schneider[1], Christian Strüber[3], Philip Tuchscherer[2], and Dmitri V. Voronine[4] — [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]Institute for Quantum Science and Engineering, Texas A&M University, College Station, TX 77840, USA

Coherent two-dimensional nanoscopy combines the principle of coherent two-dimensional spectroscopy with photoemission electron microscopy (PEEM). Using a sequence of four ultrashort laser pulses for excitation ensures high temporal resolution and detection of the emitted photoelectrons with a PEEM guarantees high spatial resolution below the optical diffraction limit. We present the concept of 2D nanoscopy for a quantum three-level system and compare the technique with conventional 2D spectroscopy. Furthermore we go into details about the experimental realization of this method and explain the evaluation of the measured data, i.e. the calculation of the local 2D nanospectra.

O 34.35 Tue 18:15 Poster E

A Point-Dipole Model for fast Computation of Plasmonic Structures and Nanoantennas — •Thorsten Schumacher[1,2], Mario Hentschel[1,2], Harald Giessen[2], and Markus Lippitz[1,2] — [1]Max Planck Institute for Solid State Research, Stuttgart — [2]4th Physics Institute, University of Stuttgart

Optical nanoantennas based on plasmonic nanostructures are a novel tool to investigate previously inaccessible single nanoobjects [ref. Natcom]. Here the optical and geometric properties of the nanoantenna play an important role and have to be designed very accurately to achieve the desired effects. Several numerical methods such as FEM, FDTD, or multiple multipoles (MMP) are available to compute the linear optical behavior of such plasmonic nanostructures. They all have in common, that the required computation time is relatively long and that a deeper understanding of the coupling behavior is not obtained. Here we present a simple and very fast alternative to these methods to predict the coupling behavior of plasmonic nanoparticles in dependence of their spatial arrangement and individual plasmonic eigenmodes. Our approach is based on the discrete dipole approximation with a maximum reduction of used dipoles. We show the range of validity and demonstrate how our method can be used to obtain a deeper understanding of plasmonic interactions in complex nanostructures.

O 34.36 Tue 18:15 Poster E

Investigations of silver and copper nanoparticles for photocatalysis — •Hannes Hartmann[1], Vladimir Popok[2], Alexandra Pazidis[1], Antje Neubauer[1], I. Barke[1], Stephan Bartling[1], Stefan Lochbrunner[1], and Karl-Heinz Meiwes-Broer[1] — [1]Institut für Physik, Universität Rostock, Universitätsplatz 3, 18051 Rostock, Germany — [2]Department of Physics and Nanotechnology, Aalborg University, 9220 Aalborg, Denmark

Clusters and nanoparticles are of significant interest for applications in catalysis. One approach is the utilization of the nanoparticles' optical properties to increase the efficiency of existing catalytic schemes for hydrogen production. Here the interaction of clusters with Ir based photosensitizers (PS) is investigated. These molecules are known to be promising systems for reduction of water to hydrogen in combination with metal-complex catalysts [1].

Using arc-discharge and magnetron sputtering cluster ion sources, silver and copper nanoparticles are produced and deposited on fused silica substrates. The PS is then deposited on cluster-covered samples. Their optical properties are characterized by absorption and fluorescence measurements. For understanding the detailed processes investigations with PEEM (photoemission electron microscopy) are planned. The current status of the experimental setup is presented.

[1] Beller et al., Angew. Chem. 2009, 48, 9962-9965

O 34.37 Tue 18:15 Poster E

Simulation of the nonlocal optical response of metallic nanostructures — •Mathias Wand, Peter Kölling, Torsten Meier, and Jens Förstner — Department Physik and CeOPP, University of Paderborn, 33098 Paderborn, Germany

Recent developments for the theoretical description of plasmonic nanostructures have shown that nonlocal effects in the motion of electrons can have a significant influence on the optical properties [1]. We present two quantum theories for the nonlinear optical response of metals and their application to the simulation of plasmonic nanostructures: The first theory is based on the time-dependent density functional theory (TDDFT) [2]. The second theory is based on the quantum generalized Vlasov equations [3], which describe the time-evolution of the single-particle Wigner functions for a two-component plasma. Both quantum theories take nonlocal effects into account. We compare our results with those from classical hydrodynamic model calculations regarding ground-state charge distribution, linear response, nonlocality, and higher harmonic generation.

[1] J. M. McMahon, S. K. Gray, and G. C. Schatz, Phys. Rev. Lett. 103, 097403 (2009).

[2] M. Wand, T. Meier, and J. Förstner, phys. stat. sol. (b) 248, 887 (2011).

[3] Y. Zeng, W. Hoyer, J. Liu, S. W. Koch, and J. V. Moloney, Phys. Rev. B 79, 235109 (2009).

O 34.38 Tue 18:15 Poster E

A SPA-LEED Study of Ag Nanowires grown on vicinal Si(557) via self-assembly — •Viktoria Meier, Ulrich Krieg, and Herbert Pfnür — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany

To be able to study plasmonic excitations on Ag-nanowires we first must find a reproducible process to prepare uniaxial nanowires of well defined width. In this work we try to measure the averaged width of the nanowires via spot profile analysis LEED (SPA-LEED).

We prepared our samples by evaporation of different amounts of silver (0.2, 0.3 and 0.5 ML) on Si(557). After a precise heating and annealing cycle a single domain system of Ag-nanowires is formed on the surface via self assembly.

Studying the so-prepared sample with SPA-LEED we show that the step-structure of the substrate remains unchanged and the step-edges remain undecorated after the evaporation process. Already at 0.3 as well as 0.5 ML the silver forms a $\sqrt{3} \times \sqrt{3}$ reconstruction on the (111) terraces.

To access the width of the nanowires we made a $(K_{\parallel}, K_{\perp})$ plot of the Γ-Point. We compute the terrace width from the angle between the diffraction-rods of the step-train and the (111)-structure.

O 34.39 Tue 18:15 Poster E

Ferroelectric-metal core-shell nanoparticles — •Thomas Kämpfe, Philipp Reichenbach, Stefan Grafström, and Lukas M. Eng — Institute of Applied Photophysics, University of Technology Dresden, 01062 Dresden

The optical properties of plasmonic nanoparticles (NPs) are widely used in linear-optical microscopy techniques as well as in many nanotechnological applications. However, in coherent nonlinear optical microscopy the narrow adjustment range of the localized surface plasmon (LSP) resonance wavelength practically restricts the application to far-off-resonant excitation, hence dramatically limiting the efficiency of the invoked nonlinear processes. Here, we show how to increase the nonlinear particle scattering by using dielectric-metallic core-shell NPs. Such a core-shell nanosystem provides plasmon-resonance tuning from the visible into the near-infrared wavelength range, allowing to resonantly excite LSPs with standard femtosecond laser sources. Moreover, a ferroelectric core will give rise to strongly enhanced second-harmonic generation due to the field enhancement produced by the plasmonic shell. We demonstrate (a) the fabrication steps for $BaTiO_3$@Au core-shell NPs, (b) the optically controlled in-situ adjustment of their plasmonic resonance by laser-induced metal precipitation [1], and (c) the ability of such $BaTiO_3$@Au core-shell NPs to emit enhanced SHG. The approach sketched here is very versatile, and paves the way to nonlinear-optical read-out of nearfields by means of a single core-shell NP probe via the emitted second-harmonic radiation.

[1] T.Härtling *et.al.*, Nanotechnology **21**, 145309 (2010)

O 34.40 Tue 18:15 Poster E

Fabrication of bow-tie like infrared antennas with small gaps by nanosphere lithography — Hendrik Janssen, •Jón Mattis Hoffmann, and Thomas Taubner — I. Institute of Physics (IA), RWTH Aachen University, Sommerfeldstraße 14, 52074 Aachen, Germany

Infrared absorption spectroscopy allows for the investigation of characteristic molecule absorption bands of sample materials by directly probing molecular vibrations. The sensitivity of infrared spectroscopy has been increased by several orders of magnitude with optical antennas.[1-3] Decreasing the distance between two antennas leads to antenna coupling and increased field-enhancement [4], resulting in even higher enhancement factors over non-coupling antennas.

In this work we present metallic bow-tie like structures with gap sizes down to sub 20 nm. To prepare these structures we use the easy method of nanosphere lithography (NSL) and two steps of evaporation on a tilted sample. For spectral characterization of the infrared resonances we use polarization resolved far-field measurements.

[1] R. Adato et al.; PNAS, 106, 19227 (2009)
[2] F. Neubrech et al.; PRL 101, 157403 (2008)
[3] R. Bukasov et al.; Analyt. Chem. 81, 4531 (2009)
[4] P. J. Schuck, et al, Phys. Rev. Lett. 94, 017402 (2005)

O 34.41 Tue 18:15 Poster E

Leakage radiation microscopy of laterally manipulated surface plasmons — •Manuel Roth, Stephen Riedel, Paul Leiderer, Elke Scheer, and Johannes Boneberg — Universität Konstanz

In a Kretschmann-configuration for an ATR (attenuated total reflection) setup, we excite SPPs (surface plasmon polaritons) on thin gold layers with a laser diode at 965 nm. Due to natural surface roughness, a fraction of the SPPs is scattered into the half space above the metal layer and recorded by a camera on top of a microscope (leakage radiation microscopy). Standing wave patterns and scattering centers can be observed on the images.

We report on SPP interference patterns which are created by different surface structures. The results are compared to simulations done by a FDTD (finite-difference time-domain) algorithm provided by Lumerical Solutions.

O 34.42 Tue 18:15 Poster E

Plasmonically enhanced electro-optical effects in metal-semiconductor nanodevices — •Markus Parzefall[1], Johannes Kern[1], Monika Emmerling[2], Martin Kamp[2], Jord C. Prangsma[1], and Bert Hecht[1] — [1]Experimental Physics 5, University of Würzburg, Germany — [2]Technical Physics, University of Würzburg, Germany

Surface plasmon enhanced internal photoemission in nanostructured Schottky devices has recently gained attention due to its promising application in photodetection and solar energy conversion. Due to their resonant nature, metallic nanostructures have shown to increase the photocurrent generated in such devices by orders of magnitude. We experimentally investigate electro-optical effects in nanostructured Schottky diodes based on gold and titanium dioxide. Our main focus lies on the evaluation of new design principles for optimized incident photon to current conversion efficiency, spectral tunability and the achievement of a deeper understanding of the underlying physics.

O 34.43 Tue 18:15 Poster E

Numerical study of circular dichroism in bi-chiral plasmonic crystals — •Yevgen Grynko[1], Jens Förstner[1], Torsten Meier[1], André Radke[2], Timo Gissibl[2], Paul V. Braun[3], and Harald Giessen[2] — [1]Department of Physics & CeOPP, University of Paderborn, Warburger Str. 100, D-33098 Paderborn, Germany — [2]4. Physikalisches Institut, University of Stuttgart, 70569 Stuttgart, Germany — [3]Department of Materials Science and Engineering, Frederick Seitz Materials Research Laboratory, Beckman Institute, University of Illinois at Urbana-Champaign, Urbana, IL 61801, USA

We study the optical properties of bi-chiral plasmonic nanostructures using the Discontinuous Galerkin Time Domain method [1], utilizing its advantages in the description of nanostructures with complex shapes. We simulate experimental measurements of transmission spectra of silver helix structures presented in [2]. Our numerical results reproduce the phenomenon of selective transmission of different circular polarizations well and qualitatively agree with the experiment for all types handednesses of bi-chiral crystals. The numerical analysis of the near fields provides information towards an understanding of the effects.

[1] J. S. Hesthaven, T. Warburton, 2002, J. Comp. Phys., 181, 186-221. [2] A. Radke, T. Gissibl, T. Klotzbücher, Paul V. Braun, and H. Giessen, 2011, Adv. Mater., 23, 3018.

O 34.44 Tue 18:15 Poster E

Enzymatically generated silver nanoparticles for surface enhanced Raman spectroscopy (SERS) — •Henrik Schneidewind[1], Karina Weber[1,2], Dana Cialla[1,2], Marco Diegel[1], Roland Mattheis[1], Andreas Berger[3], and Jürgen Popp[1] — [1]Institute of Photonic Technology (IPHT) Jena, Germany — [2]Institute of Physical Chemistry and Abbe-Center of Photonics, Friedrich-Schiller University Jena, Germany — [3]Max Planck Institute of Microstructure Physics Halle, Germany

Silver nanoparticles (Ag-NP) synthesized by an enzymatic induced growth process onto solid substrates form structures called as desert roses or nanoflowers. In order to customize the enzymatically grown nanoparticles to analytical applications in bio-molecular research, studies were carried out on the time evolution of the formation of the Ag-NP, their morphology, and their chemical composition. Therefore, Ag-NP films of different densities were investigated using SEM, TEM as well as energy dispersive X-ray spectroscopy. The surface coverage of substrates with Ag-NP and the maximum particle height were determined using Rutherford backscattering spectroscopy. It is shown, that the desert rose like Ag-NP consist of single crystalline silver plates containing only pure silver. Surface enhanced Raman spectroscopic (SERS) measurements of the vitamin riboflavin incubated on the Ag-NP are shown as an exemplary application for quantitative analysis.

O 34.45 Tue 18:15 Poster E

Electroluminescence in STM junction: nanostructures on Cu(3)N insulating layer — •Anna Strozecka, Jingcheng Li, Gunnar Schulze, Martina Corso, Katharina J. Franke, and Jose I. Pascual — Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, 14195 Berlin

Photons emitted in a scanning tunneling microscope (STM) junction can provide rich information about the electronic structure of investigated systems. However, on metal surfaces the light emission spectra are usually dominated by plasmonic excitations of the tip-sample cavity and the direct optical transitions are strongly quenched due to the short lifetime of the involved resonances. The decoupling from the metal support is neccessary in order to observe light emission directly from the nanostructure. Our experiments aim at getting closer insight into the coupling between plasmonic and electronic degrees of freedom in such systems. We investigated different types of nanostructures grown on Cu(3)N insulating layer on Cu(110). In three-dimensional Cu(3)N nanocrystals the narrow resonances corresponding to localized images potential states give rise to a direct optical transition. We studied also light emitted from molecules supported on a single Cu(3)N layer. The resulting spectra show that the molecular fluorescence is mediated by the plasmonic excitations in the cavity. Depending on the molecular structure we observe enhancement or quenching of the light emission.

O 34.46 Tue 18:15 Poster E

Fano resonances in plasmonic nanostructures — •Manuel Gonçalves and Othmar marti — Ulm University - Inst. of Experimental Physics, Albert-Einstein-Allee 11, 89069 Ulm, Germany

Fano resonances arise from the interference between a resonant process and the continuum (background) [1]. Recently, it was found that resonances in plasmonic nanostructures may also give rise to asymmetric resonance line shapes (Fano modes) [2]. These modes arise from interferences between electric dipole resonances, between electric dipole and quadrupole and, in some cases, between electric dipole and magnetic dipole. On the other hand, resonant modes in arrays of gold nanospheres have pronounced dips in the transmission spectrum and large figure of merit (FOM)[3]. These resonances are very sensitive to changes in the refractive index of the medium and are therefore good candidates for sensing applications.

We present a study of the Fano resonances in several plasmonic nanostructures, using the finite-element method (COMSOL Multiphysics). The dependence of the resonances on the excitation conditions, shape, size of the nanostructures and embedding medium was investigated.

[1] U. Fano, Phys. Rev., 124 1866 (1961).
[2] B. Lukyanchuk *et al.*, Nature Materials, 9 707 (2010).
[3] Arseniy I. Kuznetsov *et al.*, ACS Nano, 5 4843 (2011).

O 34.47 Tue 18:15 Poster E

Plasmons in Pb nanowire arrays : Between one and two dimensions — •Tammo Block, Christoph Tegenkamp, Jens Baringhaus, Karthiga Kanthasamy, and Herbert Pfnür — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstrasse 2, 30167 Hannover, Germany

Electron energy loss spectroscopy with both high energy and momentum resolution (ELS-LEED) was used to investigate the plasmon dispersion of arrays of Pb nanowires in the monolayer regime on a vicinal Si(557) substrate. While for coverages close to the physical monolayer (at 1.3ML) a true one-dimensional (1D) plasmon loss can be found, a wavelength-dependent transition from 1D to 2D properties takes place in the range from 1.2 to 1.4 monolayers. Due due to the high anisotropy in the system at all coveragess, the dispersion curves exhibit 1D characteristics in both directions, perpendicular and along the Pb wire direction. The Pb-induced refacetting of the Si(557) surface, which depends on Pb coverage seems to be the reason for this behavior, because both effective system sizes and coupling strength between miniterraces changes while increasing the Pb coverage.

O 34.48 Tue 18:15 Poster E

Interaction of Carbon Nanotubes with periodic Plasmonic Surfaces — •Christian Lehmann, Eser Akinoglu, Michael Giersig, and Stephanie Reich — FU Berlin, Fachbereich Physik, Arnimallee 14, 14195 Berlin

We investigate the interaction of carbon nanotubes with plasmonic particles using Raman spectroscopy. Our goal is to understand the influence of the shape and dielectric environment of the plasmonic particles on the Raman signal. Therefore we use shadow nanosphere lithography to create plasmonic surfaces with homogeneously shaped triangular gold particles aligned in a hexagonal lattice structure. Depending on the deposition parameters, the plasmonic resonance was shifted to available excitation wavelengths for Raman measurements. The parameters were obtained by finite difference time domain simulations, which agree well with the measured resonances. The resonances were obtained using dark field and UV/VIS absorption spectroscopy. As marker molecules we used carbon nanoubes because of their well known Raman spectrum. We observed an additional plasmonic amplification of the Raman signal. The effect was observed only when the particle was in resonance with the exciting laser wavelength. Under certain conditions additional Raman modes were observed. These modes are strongly dependend on the distance between the carbon nanotube and the plasmonic particles. We will discuss the origin of these additional modes. Furthermore, a strong luminescence amplification of the gold particles was observed for certain shapes. It is likely that this effect originates from clustering of the gold particles.

O 34.49 Tue 18:15 Poster E

Fabrication and characterization of complex nano antennas generated by evolutionary algorithms — •Oleg Selig, Thorsten Feichtner, Markus Kiunke, and Bert Hecht — Nano-Optics & Biophotonics Group, Experimentelle Physik 5, Physikalisches Institut, Wilhelm-Conrad-Röntgen-Center for Complex Material Systems, Universität Würzburg, Am Hubland, D-97074, Würzburg, Germany

Plasmonic nano antennas are used to enhance visible light-matter interaction on the nanometer scale and thus can improve e.g. single molecule detection and the coupling of light into plasmonic waveguides. Most of the established nano antenna designs are inspired by well-known concepts from the radio-frequency regime. In order to find new designs, which account for the plasmonic behavior of metals in the optical regime we used an evolutionary algorithm which finds optimized structures for defined properties. The working principal is basically to etch holes in an array of gold in the right position and size to get an good value for the desired property and then recombine and mutate good structure to further improve them. By using rounded corners, gaussian excitation and realistic material thickness a very good approximation to feasible experimental conditions was achieved. For the realization we dropcasted mono crystalline gold flakes on ITO-covered glass. The structures calculated by the evolutionary algorithms were then written by means of focused ion beam milling. The optical properties were measured by confocal two-photon-photo-luminescence and compared to the simulation results, showing a substantial agreement.

O 34.50 Tue 18:15 Poster E

Fabrication of nanometer-sized gaps between nanoantenna dimers by photo-chemical metal deposition for SEIRS measurements — •Christian Huck[1], Daniel Weber[1], Frank Neubrech[1], Julia Katzmann[2], Thomas Härtling[2], Andrea Toma[3], Enzo Di Fabrizio[3], and Annemarie Pucci[1] — [1]Kirchhoff-Institute for Physics, Im Neuenheimer Feld 227, Heidelberg, Germany — [2]Fraunhofer Institute for Non-Destructive Testing, Dresden, Germany — [3]Istituto Italiano di Tecnologia (IIT), Genova, Italy

Metal nanoparticles exhibit surface plasmons, which are able to strongly enhance electromagnetic fields when excited by electromagnetic radiation. If the resonance frequency matches specific IR active vibrations of molecules, the detection of such vibrations of molecules adsorbed on the antennas can be improved up to 5 orders of magnitude. Additional enhancement can be achieved by exploiting the extraordinary field enhancement of two antennas interacting across a very small gap. Constraints in the lithographic fabrication limit the gap size to $\geq 20nm$.

To overcome these limitations, we applied the method of optically induced metal deposition to lithographically prepared gold nanoantennas. The technique was demonstrated for nm-sized structures and is applied here in the μm range.Covering the nanorods on the substrate with a solution of HAuCl4 and illuminating them by a focused 532nm laser beam leads to the reduction of the gold salt and to a gradual growth of the nanorods. The changes of the optical particle properties can be monitored by IR-spectroscopy.

O 34.51 Tue 18:15 Poster E

Transfer of Angular Momentum by Circularly Polarized Near Fields — •Peter Klaer, Florian Schertz, Keno Krewer, Gerhard Schönhense, and Hans-Joachim Elmers — Institut für Physik, Johannes Gutenberg-Universität Mainz, 55122 Mainz

A locally rotating electrical near field generated by special nanoantennas might have properties similar to a circularly polarized plane light wave.[1] In particular, the photons of the near field possess spin momenta of $\pm\hbar$ and all effects related to the photon spin should exist for near fields as well. The plasmonic near field concentrates large amounts of electromagnetic energy and, for rotating fields, also large amounts of photon spin momentum in a very small spatial volume far below the diffraction limit.

We show first results confirming the transfer of angular momentum by circularly polarized near fields using spin-polarized photoemission electron microscopy (SP-PEEM) to detect the spin polarization of electrons excited by 100fs light pulses with 800nm wavelength from localized plasmons on a Ag/GaAs(100) surface. We thank the DFG EL172/16-1 for financial support.

[1] R. Mohammadi et al., Appl. Phys. B, publ. online (2011).

O 34.52 Tue 18:15 Poster E

Fabricating Confined Nanorod Arrays for Nano-optical Applications — •Vera Hoffmann[1], René Kullock[1], Mathias Böhm[1], Gunther Scheunert[2], and Lukas M. Eng[1] — [1]Department of Applied Photophysics, TU Dresden, Dresden, Germany — [2]Department of Physics and Astronomy, Queen's University Belfast, Belfast, UK

Two-dimensional nanorod arrays made of materials such as gold, silver, cobalt etc. show optical properties [1,2] that provide the basis for novel plasmonic devices [3]. To go a step further towards low-cost integration into existing technologies, the electrochemical growth of such nanorods in self-organized porous alumina masks deposited onto a thin gold film is of great interest. In this study, we present a novel technique in which we restrict the nanorod growth to a confined nanoscale surface area only. By pre-structuring the underlying gold metal film, the growth of nanorods is confined to the edges of this structured area. Hence, the geometry and the plasmonic properties of the arrays can be modified, which makes them very promising and tunable for applications such as waveguides, nanoantennas, or in data storage devices.

[1] R. Kullock et al., Optics Express 16, 21671 (2008) [2] R. Kullock et al., J. Opt. Soc. Am. B 27, 1819 (2010) [3] A.V. Kabashin et al., Nat. Mater. 8, 867 (2009)

O 34.53 Tue 18:15 Poster E

Towards Quantum Plasmonics on a Chip: An Efficient Photon-Plasmon-Coupler for Single-Mode Operation — •Günter Kewes[1], Andreas W. Schell[1], Rico Henze[1], Sven Burger[2], and Oliver Benson[1] — [1]Institut für Physik, Humboldt-Universität zu Berlin — [2]Konrad-Zuse-Zentrum für Informationstechnik Berlin

Not only the ability of surface plasmon polaritons to guide energy

and information below the diffraction limit of light [1] but also their quantum nature [2], hold great potential for highly integrated photonic/plasmonic circuits or on-chip experiments. We numerically investigate and design a photon to plasmon coupler which consists of a tapered dielectric waveguide and a V-shaped metal part, using adaptive finite-element methods. We pay special attention on an easy-to-fabricate approach and focus on single-mode operation since this will simplify quantum plasmonic experiments.

[1] W. L. Barnes et al., "Surface plasmon subwavelength optics", Nature 424, 824-830 (2003) [2] A. V. Akimov et al., "Generation of single optical plasmons in metallic nanowires coupled to quantum dots", Nature 450, 402-406 (2007)

O 34.54 Tue 18:15 Poster E

Near-Field of Strongly Coupled Plasmons - Uncovering Dark Modes Using PEEM — •Florian Schertz[1], Marcus Schmelzeisen[2,3], Reza Mohammadi[2,4], Maximilian Kreiter[2], Hans-Joachim Elmers[1], and Gerd Schönhense[1] — [1]Insitut für Physik, Johannes Gutenberg-Universität, D-55099 Mainz, Germany — [2]Max-Planck-Institut für Polymerforschung, D-55128 Mainz, Germany — [3]Center of Smart Interfaces, TU Darmstadt, D-64287 Darmstadt, Germany — [4]Department of Physics, Payame Noor University, Tehran, Iran

Strongly coupled plasmons in a system of individual Au nanoparticles placed at sub-nm distance to a Au film (nanoparticle-on-plane, NPOP) are investigated using two complementary single particle spectroscopy techniques. Optical scattering spectroscopy exclusively detects plasmon modes that couple to the far-field via their dipole moment (bright modes). By using photoemission electron microscopy (PEEM) we detect in the identical NPOPs near-field modes that do not couple to the scattered far-field (dark modes) and are characterized by a strongly enhanced non-linear electron emission process. To our knowledge, this is the first time that both far-field and near-field spectroscopy are carried out for identical individual nanostructures interacting via a sub-nm gap. Strongly resonant electron emission occurs at excitation wavelengths far off-resonant in the scattering spectra. Simulations based on classical electrodynamics confirm the observed differences of near- and far-field characteristics for a strongly coupled plasmonic model system. We thank DFG EL172/16-1 for financial support.

O 34.55 Tue 18:15 Poster E

Surface passivation and dark field spectroscopy of metallic nanocones — •Dominik Gollmer, Christian Schäfer, Yuliya Fulmes, Andreas Horrer, Dieter P. Kern, and Monika Fleischer — Institut für Angewandte Physik, Eberhard Karls Universität Tübingen, Auf der Morgenstelle 10, 72076 Tübingen

The external electromagnetic excitation of plasmonic nanostructures is accompanied by a localized enhanced near field, which makes these structures promising candidates for several applications like near-field imaging or sensing. We fabricated conical nanostructures with sharp tips (tip radii less than 10 nm) [1] using different unique fabrication methods. Because of their shape, these nanocones are suitable candidates for the applications mentioned above. The tunability of the optical properties of nanocones is an important precondition for efficient excitation. We showed via dark field spectroscopy of single structures that this can be achieved by variation of size, aspect ratio and material. For non-stable materials a passivation is essential to keep the optical properties constant over time. Aluminum oxide has been suggested as an appropriate material for this purpose [2]. We showed that it is possible to passivate silver nanocones by oxidized thin sputtered aluminum layers. The fabrication processes will be presented together with dark field images and spectra of gold and silver nanocones in different sizes. The changes in unprotected and passivated silver cones with time will be illustrated by SEM and dark field images. [1] M. Fleischer et al.; Nanotechnology 21 (2010); 065301 [2] C. A. Barrios et al.; The Journal of Physical Chemistry C 113 (2009); 8158-8161

O 34.56 Tue 18:15 Poster E

Interaction of Light and Surface Plasmon Polaritons in Ag Islands Studied by Nonlinear Photoemission Microscopy — Philip Kahl, •Simone Wall, Niemma Buckanie, Pierre Kirschbaum, Simon Sindermann, Michael Horn-von Hoegen, and Frank-J. Meyer zu Heringdorf — Faculty of Physics and Center of Nanointegration Duisburg-Essen (CeNIDE), Universität Duisburg-Essen, Lotharstrasse. 1, 47057 Duisburg

Two Photon Photoemission Microscopy was used to study the interaction of femtosecond laser pulses with Ag islands on Si(111) and SiO_2. The fs laser pulses initiate surface plasmon polariton (SPP) waves at the edges of the island. The superposition of the electrical fields of the fs laser pulses with the electrical fields of the SPP results in a moiré pattern, the analysis of which gives access to the wavelength and direction of the SPP wave. If the SPPs reach edges of the Ag islands, they may be converted back into light waves. The incident and refracted light waves result in an interference pattern that can again be described with a moiré pattern, showing that Ag islands can be used as plasmonic beam deflectors for light.

O 34.57 Tue 18:15 Poster E

Calculation of enhanced up-conversion intensity from Er^{3+} ions near gold nanospheres — •Florian Hallermann[1], Stefan Fischer[2], Deepu Kumar[1], Alexander Sprafke[1], Jan Christoph Goldschmidt[2], and Gero von Plessen[1] — [1]Institute of Physics (1A), RWTH Aachen University, 52056 Aachen, Germany — [2]Fraunhofer ISE, Heidenhofstr. 2, 79110 Freiburg, Germany

In conventional silicon solar cells, photons with energies below the silicon band gap (1.12 eV) do not contribute to current generation. The near-infrared part of the solar spectrum could be exploited by using up-conversion processes, such as the excitation of electrons via sequential absorption of infrared photons in suitable rare-earth ions. The electrons subsequently relax from the final state by emitting photons whose energy is high enough to be absorbed in the silicon. Here, we show on the basis of model calculations by how much the up-conversion intensity from Er^{3+} ions can be enhanced using spherical gold nanoparticles. In the vicinity of the nanoparticles, the excitation rate of the ions is changed due to the near-field of the particles. In addition, the relaxation times of all involved excited states of the ions are changed by the presence of metal nanoparticles due to energy transfer from the ions to the nanoparticles, which offer additional radiative and nonradiative decay channels. We calculate the effects that these changes have on the up-conversion intensity by using Mie theory combined with a rate equation system. We find a 17% enhancement for the most prominent up-conversion line emitted by Er^{3+} ions that are distributed over a volume around a 200 nm particle.

O 34.58 Tue 18:15 Poster E

Theoretical and Experimental Studies of Surface Plasmon Polaritons on Gold Microstructures Using Photoemission Electron Microscopy — •Martin Piecuch[1], Christian Schneider[1], Daniela Bayer[1], Alexander Fischer[1], Pascal Melchior[1], Christoph Lemke[2], Michael Bauer[2], and Martin Aeschlimann[1] — [1]TU Kaiserslautern — [2]Christian-Albrechts-Universität zu Kiel

Collective electron excitations at metal surfaces are currently a rapidly developing research field. Surface plasmon polaritons (SPPs) for instance are promising candidates for future ultrafast subwavelength electronic devices. By using photoemission electron microscopy (PEEM), we investigate coherent excitations with spatial resolution which is well below the diffraction limit defined by the laser wavelength. Applying a laser pulse to a gold microstructure results in a beating pattern due to interference between the incident light source and excited SPPs which can be observed by PEEM. Using a phase stabilized Mach-Zehnder-interferometer that manipulates the excitation spectrum of the laser enables us to control the phase sensitive interference pattern. Theoretical simulations of the full electrical field with a fast algorithm based on the Huygens principle give insight into the underlying SPP dynamics. We show the high potential of the developed algorithm by a comprehensive comparison between experimental data and the simulation.

O 34.59 Tue 18:15 Poster E

Coherent Control of the Electron Emission from Metal Nanotips due to Ultrashort Laser Pulses — •Steve Lenk and Erich Runge — Institut für Physik und Institut für Mikro- und Nanotechnologien, Technische Universität Ilmenau, 98693 Ilmenau, Germany

Recent experiments show the possibility for a novel scanning microscope using ultrafast laser-induced photoelectron emission. The analysis of the experimental data requires a detailed theoretical knowledge of the emission process and the underlying physics. We investigate the electron emission from sharp gold nanotips illuminated by ultrashort femtosecond laser pulses theoretically. The emission processes under discussion for few-femtosecond laser pulses are multiphoton emission and optical field emission. We calculate the probability current and the Wigner distribution of the emitted electrons from a numerical solution of the time-dependent Schrödinger equation via a real-space product-formula algorithm. By the use of an optimization routine, we study

the dependence of several target functions, like the emission current, on laser pulse properties and on confined potential energy profiles. By comparing experimental and theoretical findings, we can distinguish the dominant physical processes for different energy profiles and pulse shapes. Generally speaking, such investigation allow us to find optimized laser pulse properties to achieve the best electron emission characteristics for different experimental requirements.

O 34.60 Tue 18:15 Poster E

Far-field control of optical near-field enhancement — •Riko Kiessling, David Leipold, and Erich Runge — Technische Universität Ilmenau, 98693 Ilmenau, Germany

Controlling optical near-fields by shaping the temporal envolope of an incoming far-field laser pulse is a new and interesting topic with most promising applications in optical nano-circuitry. Recent experiments proof the possibility to tailor the near-fields in an arrangement of nano-antennas spatially and temporally [1].

In this theoretical work, we study how strong the fields near one out of some randomly arranged nano-anntennas can be enhanced. We quantify the relative near-field enhancement dependent on the number of far-field degrees of freedom allowed in the optimization. In particular, we consider superpositions of incident plane-waves with different frequencies, directions and polarizations. For this purpose, we explore a huge configuration space with a discrete-dipole approximation (DDA). DDA calculations are numerically cheap and inherently well suited for sytems of small antennas. The optimization itself is then performed semi-analytically.

[1] M. Aeschlimann, et. al, PNAS **107**, 5333 (2010)