HL 40: Plasmonics and nanooptics III

Time: Wednesday 10:30–13:15 Location: H32

HL 40.1 Wed 10:30 H32

3D optical Yagi-Uda nanoantenna array — •Daniel Dregely, Richard Taubert, and Harald Giessen — University of Stuttgart, Germany

Optical nanoantennas have gained a lot of interest in the past few years [1,2]. They are able to link propagating radiation and confined optical fields. Only little work has been done on complex antenna geometries on the nanoscale. In our experiments, we investigate a 3D optical Yagi-Uda nanoantenna array. Due to the high directivity of the array structure the incoming light is received efficiently at resonant wavelengths in the near-infrared (around $\lambda = 1.3$ μm).

Our 3D gold nanoantenna structure was fabricated with electron beam lithography using layer-by-layer stacking. We measured the transmission and reflection spectra of the nanoantenna array from both directions in order to examine the directive behavior of the structure. FIT-calculations agree very well with our experimental findings and confirm the concentration of the incoming plane-wave radiation to the feeding points of the antenna array.

References: [1] P. Mühlschlegel, H.-J. Eisler, O. J. F. Martin, B. Hecht, and D. W. Pohl, Science 308, 1607 (2005). [2] T. H. Taminiau, F. D. Stefani, F. B. Segerink, and N. F. van Hulst, Nature Photon. 2, 234 (2008).

HL 40.2 Wed 10:45 H32

Few-cycle nonlinear optics of single plasmonic nanoantennae — •Tobias Hanke, Günther Krauss, Daniel Träutlein, Barbara Wild, Rudolf Bratschitsch, and Alfred Leitenstorfer — Department of Physics and Center for Applied Photonics, University of Konstanz, D-78457 Konstanz, Germany

We have studied the nonlinear optical properties of single gold nanoantennae driven with few-cycle laser pulses in the near infrared [1]. Intense third harmonic emission is obtained when exciting with fundamental spectra below 1.1 eV. At higher photon energies frequency doubling and two-photon induced luminescence are observed. We relate these findings to the band structure of bulk gold, especially a two-photon resonance with the d-band transitions.

The intense third-harmonic emission enables precise detection of frequency-resolved interferometric autocorrelation traces of individual nanoantennae. We find an enhancement up to 3 orders of magnitude when driving on resonance with the fundamental plasmon mode. A sub-cycle dephasing time as short as 2 fs is measured directly in the time domain, highlighting the strong radiation coupling and ultrabroadband response of these efficient nanodevices.

[1] Hanke et al., Phys. Rev. Lett., accepted for publication.

HL 40.3 Wed 11:00 H32

plasmon-enhanced high-order harmonic generation in the vicinity of metal nanostructures — •song-jin im, anton husakou, and joachim herrmann — Max-Born-Institute for Nonlinear Optics and Short Pulse Spectroscopy, Max-Born-Str. 2a, D-12489 Berlin, Germany

Generation of high harmonics in noble gases is one of key topics of nonlinear optics, which is of a critical importance in many disciplines, for example in attosecond physics. Recently, plasmon-enhanced high-order harmonic generation became possible in the vicinity of bow-tie shaped nanostructures by pulses directly from an oscillator with MHz repetition rate. In this contribution, we simulate high-order harmonic generation by sub-TW/cm^2 pulses using large plasmon field enhancement near metallic nanostructures such as bowtie-shaped antennas or nanocones. Our simulations using a commercial software JCMwave predict intensity enhancement of 3 orders of magnitude near the surface of silver nanocones. The generation of the high harmonics was modeled using a modified Lewenstein approach taking into account the inhomogeneity of the field and the electron absorption by the metal. Our results are consistent with experimental observations for bowtie elements. Considering the generation of high harmonics in argon in the vicinity of silver nanocones, we show that harmonics numbers up to 50, corresponding to 15 nm wavelength, can be achieved using relatively low input intensity of 300 GW/cm^2, characteristic for nJ laser pulses directly from a laser oscillator with MHz repetition rate.

HL 40.4 Wed 11:15 H32

Analytic photoemission localization and switching in plasmonic nanoantennas by laser pulse shaping — Martin Aeschlimann[1], Michael Bauer[2], Daniela Bayer[1], Tobias Brixner[3], Stefan Cunovic[4], Alexander Fischer[1], Pascal Melchior[1], Walter Pfeiffer[4], Martin Rohmer[1], Christian Schneider[1], Christian Strüber[4], •Philip Tuchscherer[3], and Dmitri V. Voronine[3] — [1]Fachbereich Physik and Research Center OPTIMAS, Technische Universität Kaiserslautern, Erwin-Schrödinger-Str. 46, 67663 Kaiserslautern, Germany — [2]Institut für Experimentelle und Angewandte Physik, Universität Kiel, Leibnizstr. 19, 24118 Kiel, Germany — [3]Institut für Physikalische Chemie, Universität Würzburg, Am Hubland, 97074 Würzburg, Germany — [4]Fakultät für Physik, Universität Bielefeld, Universitätsstr. 25, 33615 Bielefeld, Germany

We experimentally achieve two-photon photoemission localization and switching on a subwavelength scale in plasmonic nanoantennas. Complex polarization-shaped laser pulses which are found in adaptive optimizations control the linear response of the nanostructure. We consider previous analytic investigations to identify the interference of two excited modes in the nanostructure as the main control mechanism. The optimal pulse shapes for switching are then found deterministically. Adaptive and analytic control schemes are compared, and agreement between both approaches is demonstrated.

HL 40.5 Wed 11:30 H32

Swichable Hot Spots in Bipyramid-Nanoresonators — •Siji Wu, Calin Hrelescu, Frank Jäckel, and Jochen Feldmann — Photonics and Optoelectronics Group, Department of Physics and Center for Nano Science (CeNS), Ludwig-Maximilians-Universität München, Amalienstrasse 54, 80799 München, Germany

Highly enhanced and strongly localized electromagnetic fields, so-called hot spots, are attractive for imaging applications, based on raman scattering or fluorescence enhancement.[1,2] Hot spots can be provided by nonspherical gold nanoparticles or nanoparticles aggregates. Here, we report on nanoresonators consisting of two bipyramidal gold nanoparticles prepared by AFM manipulation. Applying a force with the AFM allows switching between the two possible adsorption geometries of an individual bipyramid on the substrate. The plasmonic coupling between two bipyramids is different in the two configurations. Consequently, the hot spot in the nanoresonator can be switched mechanically. Furthermore, the hot spot can be located within 1nm above the substrate surface in contrast to dimer nanoresonators from spheres, rods or ellipsoids.

[1] C. Hrelescu, T.K. Sau, A.L. Rogach, F. Jäckel, J. Feldmann Appl. Phys. Lett., 94, 153113 (2009)

[2] A. Bek, R. Jansen, M. Ringler, S. Mayilo, T. A. Klar, J. Feldmann Nano Lett., 8 (2), 485 (2008)

HL 40.6 Wed 11:45 H32

Near-field measurements on nanoscopic sphere-on-plane-systems by means of PEEM — •Florian Schertz[1], Marcus Schmelzeisen[2], Hans-Joachim Elmers[1], Gerd Schönhense[1], and Max Kreiter[2] — [1]Inst. f. Physik, Johannes Gutenberg-Universität, 55099 Mainz — [2]Max-Planck-Inst. f. Polymerforschung, 55128 Mainz

Surface immobilized gold nano-spheres above a gold surface with a gap distance in the order of a nanometer act as sphere-on-plane (SOP) optical resonator systems showing unique optical properties. In the vicinity of a flat metal surface, a second resonance band red-shifted with respect to the isolated particle resonance occurs, understandable on the basis of multipole interactions of the sphere with its own mirror image in the gold film. Several theoretical and optical far-field studies of SOP resonators were performed, investigating the dependence of the resonance wavelength on the resonator geometry and dielectric properties of the spacer material [1]. The optical near-field of the system under fs-laser-radiation causes highly non-linear (n=3-5) photoemission processes strongly varying depending on the particle properties. Photoelectron microscopy turned out to be a valuable tool for the investigation of the optical near-field of individual SOPs (cf.[2]). We present the gap-resonance-induced photoemission characteristics of several SOPs (individually characterized by SEM), excited by fs-laser radiation in the range from 750nm to 850nm. This work was supported

by DFG (EL172-16) and MWFZ, Univ. Mainz. [1] A. Rueda et al., J. Phys. Chem. C 112 (2008) 14801, and Refs. therein. [2] M. Cinchetti et al., Phys. Rev. Lett. 95 (2005) 047601

HL 40.7 Wed 12:00 H32

Strong-field photoelectron emission from metal nanotips — •Max Gulde, Reiner Bormann, Alexander Weismann, Sergey Yalunin, and Claus Ropers — University of Göttingen, Courant Research Center Nano-Spectroscopy and X-Ray Imaging, Friedrich-Hund-Platz 1, 37077 Göttingen, Germany

The generation of ultrashort, localized electron pulses is of fundamental interest for future applications in time-resolved electron imaging and diffraction. Femtosecond electron sources of great spatial coherence make use of a combination of local field enhancement at metal nanotips and nonlinear photoelectric effects. Previous studies have resulted in a controversial debate about the underlying physical processes.

Here, we present our most recent theoretical and experimental results regarding ultrafast photoelectron emission from nanometric gold tips. For the first time, we conclusively show the transition between the multiphoton and the optical field emission (i.e. tunneling) regimes. Direct evidence for this transition is found from both the power dependence of the total current and the spatial characteristics of the resulting electron beam. The results are supported by theoretical modeling.

HL 40.8 Wed 12:15 H32

Dark-Mode Plasmonic Nanorod Cavity — •Johannes Kern, Swen Grossmann, Jer-Shing Huang, Paolo Biagioni, and Bert Hecht — Experimental Physics 5, University of Würzburg, Germany

We report ultra-small nanoplasmonic cavities consisting of a self-assembled, side-by-side aligned gold nanorod dimer. The rods are 50-70 nm long and are separated by a 3 nm gap. The structure corresponds to a finite piece of a two-wire transmission line with two highly reflective open ends which supports a quasi-TE fundamental mode which propagates along the transmission line. Reflection at the end caps leads to length-dependent Eigenmodes, whose energies are determined by the cavity length and the phaseshift introduced upon reflection. Unlike the dipolar longitudinal and transverse plasmon resonances that are also supported by the structure, the fundamental cavity mode is a dark quadrupol mode.

Nevertheless the cavity mode is experimentally accessible by excitation of electron-hole pairs in the gold bandstructure, which act as local dipole sources. The ultra-small mode volume and comparatively high Q-factor leads to a high selectivity of the cavity and the electron-hole pairs preferentially decay into the cavity resonance. Therefore luminescence spectra of the cavities clearly show the peak of the cavity mode. The wavelength of the cavity mode depends on the cavity length and lies in the VIS region, consistent with FDTD simulations and analytical modeling.

The ultra-small mode volume and high Q-factor make our cavities promising candidates to study lasing and/or strong coupling effects.

HL 40.9 Wed 12:30 H32

Temperature related nanoantenna extinction in infrared range — •Chung Hoang, Frank Neubrech, Makus Klevenz, Robert Lovrincic, Olaf Skibbe, and Annemarie Pucci — Kirchhoff-Institut für Physik der Universität Heidelberg, Im Neuenheimer Feld 227, 69120 Heidelberg

We present important progress in the experimental studies of single-crystalline lead nanorods grown on Si(557) vicinal surfaces by self-assembling process in ultra-high vacuum. The growth of such nanorod arrays is governed by four experimental parameters: substrate temperature, surface energy, deposition rate, and amount of deposited lead. Upon cooling, strong enhancement of the infrared signal at resonance is observed, indicating the increase of extinction-cross section. This scenario can be attributed to the reduction of electron scattering events where electron - phonon scattering is the main factor that is involved in this process. Below half of the Debye temperature, the maximum resonant antenna extinction is nearly temperature independent, indicating residual electron scattering at surfaces.

HL 40.10 Wed 12:45 H32

Polarization-independent chiral split-ring resonator arrays with colossal optical activity — •Max Wunderlich, Sebastian Engelbrecht, Alexey Shuvaev, and Andrei Pimenov — Experimentelle Physik IV, Universität Würzburg

We have studied the optical activity of bi-layered split-ring resonator arrays. They form chiral quasi-molecules due to inductive coupling. We have examined these structures with the instruments of quasioptical terahertz-spectroscopy. Our investigation shows that such systems can produce a colossal optical activity of 600 degree per wavelength. This results might lead to negative refraction due to chirality. Furthermore we present a way to effectively suppress polarization-dependent behavior of split-ring resonator arrays by introducing C_n symmetries. Thus we have demonstrated a way to realize a ultra-thin orientation-independent polarization rotator.

HL 40.11 Wed 13:00 H32

Efficient surface-plasmon-polariton excitation on nanoparticle structures by inclined incident light — •Andreas Seidel, Wei Cheng, Andrey Evlyukhin, Carsten Reinhardt, and Boris Chichkov — Laser Zentrum Hannover e.V., Hollerithallee 8, 30419 Hannover

We study the features of local surface plasmon polariton (SPP) excitation on single and chains of gold nanoparticles positioned near a gold surface using a light beam under inclined incidence. It is shown that by tuning the incident angle and the parameters of the surface nanoparticle structure one could obtain symmetric or asymmetric excitations of SPP beams propagating along certain directions depending on the particle/chain distances. The reasons and conditions for this behaviour and efficiency of SPP excitation as a function of the incident angle are studied. It is demonstrate that the SPP excitation efficiency strongly depends on the incident angle. Adjusting the incident angle to the maximum field component perpendicular to the metal dielectric interface can lead to a large increase of SPP excitation efficiency. In the case of nanoparticle chains the symmetric or asymmetric patterns of the SPP distributions are the result of the interference of the scattered waves generated by each nanoparticle in a structure. The theoretical consideration is based on the Green*s function technique for the Maxwell equations of the total electric field and on the point-dipole approximation. Experimental investigation is realized by leakage radiation microscopy in real and reciprocal space.