O 85: Plasmonics and nanooptics V

Time: Friday 10:30–13:00 Location: MA 005

O 85.1 Fri 10:30 MA 005

Spectral near and far field characteristics of single plasmonic nanoantennas in the infrared — •F. Neubrech[1], P. Alonso Gonzalez[2], P. Albella[3], C. Huck[1], F. Casanova[2], L. E. Hueso[2], J. Chen[2], F. Golmar[2], A. Pucci[1], J. Aizpurua[3], and R. Hillenbrand[2] — [1]Kirchhoff-Institut für Physik, Heidelberg, Germany — [2]CIC nanoGUNE Consolider, San Sebastian, Spain — [3]Center for Materials Physics, San Sebastian, Spain

The optical properties of metal nanoparticles are dominated by plasmonic resonances, which cause a huge field enhancement in the vicinity of the nanoparticles. Such huge near-field enhancements can be exploited for SEIRA or SERS. In both techniques one pre-condition is a good match between the vibrational excitation and the plasmonic one. Instead of near-field characteristics, far-field quantities are used to characterize the tuning, since they are easier to obtain experimentally. However, the use of far-field quantities will present several problems, since there is a shift between the near and far-field peak energies. In order to demonstrate this effect experimentally we carried out microscopic infrared spectroscopy fot the far-field optical, which enables us to record far-field spectra of single antennas. Using IR scattering near-field optical microscopy near-field intensities of the same antennas were recorded at a wavelength of 9.3 microns. Comparing the near and far-field response at the given wavelength for antennas with different lengths, we observed a significant shift of the near field peak intensity to lower energies, which is in perfect agreement with FDTD simulations.

O 85.2 Fri 10:45 MA 005

Local Enhancement of Optical Chirality in Planar and 3D Plasmonic Nanostructures — •Martin Schäferling, Mario Hentschel, Daniel Dregely, and Harald Giessen — 4th Physics Institute, Research Center SCoPE and Research Center SimTech, University of Stuttgart, Pfaffenwaldring 57, 70550 Stuttgart, Germany

Chirality – the absence of mirror symmetry – is an integral component of our world. The chirality of electromagnetic fields can be quantified by the so-called optical chirality [1]. Fields with high optical chirality can be utilized to enhance the sensitivity of enantiomer sensors [2]. Such fields can be generated by plasmonic nanostructures.

We numerically calculate and visualize the enhancement of optical chirality in the near-field of different planar and three-dimensional nanostructures. For practical applications not only the absolute values of the enhancement but also the shapes of the regions with enhanced optical chirality are important. Therefore, we present three-dimensional maps of the enhancement which allows a straightforward comparison of the different structures.

We show that planar structures can provide easy access to these chiral fields. As also the fabrication process is simple compared to three-dimensional structures, they are very well-suited for applications such as enantiomer sensing. Three-dimensional structures, on the other hand, allow higher enhancement of optical chirality.

[1] Y. Tang and A.E. Cohen, Phys. Rev. Lett. 104, 163901 (2010).
[2] E. Hendry et al., Nat. Nanotechnol. 5, 783 (2010).

O 85.3 Fri 11:00 MA 005

Three-dimensional chiral plasmonic oligomers — •Mario Hentschel[1,2], Martin Schäferling[1], Thomas Weiss[1], Hans-Georg Kuball[3], Na Liu[4], and Harald Giessen[1] — [1]4. Physikalisches Institut und Research Center SCoPE, Universität Stuttgart — [2]Max-Planck-Institut für Festkörperforschung, Stuttgart — [3]Fachbereich Chemie, Lehrstuhl für Physikalische Chemie, Universität Kaiserslautern — [4]Department of Electrical and Computer Engineering, Rice University

We demonstrate a chiral optical response in stacked arrangements of plasmonic nanostructures. They exhibit resonant plasmonic coupling between particles of similar size and dipole moment. Moreover, we demonstrate that such particle ensembles possess the capability to encode their three-dimensional arrangement in unique and well modulated spectra, making then ideal candidates for a three-dimensional chiral plasmonic ruler [1]. Our results are crucial for the future design and improvement of plasmonic chiral optical systems, e.g., for ultrasensitive enatiomer sensing on the single molecule level [2], for the design of chiral optical modulators and devices [3] as well as applications in medicine and drug development.

[1] Liu, N. et al., Science 332, 1407-1410 (2011).
[2] Hendry, E. et al., Nat. Nanotech. 5, 783-787 (2010).
[3] Gansel, J. K. et al., Science 325, 1513-1515 (2009).

O 85.4 Fri 11:15 MA 005

Simulation of Plasmonic Nanostructures using the Discontinuous Galerkin Time-Domain Method on Graphics Processing Units — •Richard Diehl[1], Jens Niegemann[2], and Kurt Busch[3] — [1]Institut für Theoretische Festkörperphysik and DFG-Center for Functional Nanostructures (CFN), Karlsruhe Institute of Technology (KIT), Wolfgang-Gaede-Straße 1, 76131 Karlsruhe, Germany — [2]IFH - Lab for Electromagnetic Fields and Microwave Electronics ETH Zürich, Gloriastrasse 35, 8092 Zürich, Switzerland — [3]Humboldt-Universität zu Berlin, Institut für Physik, AG Theoretische Optik, Newtonstr. 15, 12489 Berlin, and Max-Born-Institut, Max–Born–Str. 2A, 12489 Berlin, Germany

The discontinuous Galerkin time-domain (DGTD) method is a powerful method to explore the electromagnetic properties of nano-scale plasmonic and dielectric systems. Here, we present the method's advantages and disadvantages when implemented to run on graphic processing units (GPUs). The GPU's superior performance is demonstrated for a realistic split-ring resonator on membrane setup which is characterized by both, optical spectroscopy and electron energy loss spectroscopy. Compared to modern CPU hardware, GPU-based DGTD yields up to two orders of magnitude decreased computational time.

O 85.5 Fri 11:30 MA 005

Plasmon resonances in atomic-scale gaps — •Johannes Kern[1], Swen Grossmann[1], Tim Häckel[1], Nadezda Tarakina[2,3], Monika Emmerling[3], Martin Kamp[3], Jer-Shing Huang[4], Paolo Biagioni[5], Jord C. Prangsma[1], and Bert Hecht[1] — [1]Experimental Physics 5, University of Würzburg, Germany — [2]Experimental Physics 3, University of Würzburg, Germany — [3]Technical Physics, University of Würzburg, Germany — [4]Department of Chemistry, National Tsing Hua University, Taiwan — [5]Dipartimento di Fisica, Politecnico di Milano, Italy

We experimentally investigate the plasmon resonances of side-by-side aligned single-crystalline gold nanorod dimers. Robust gaps between the particles reaching well below 1 nm are obtained by reproducible self-assembly. For such atomic-scale gaps extreme splitting of the symmetric and anti-symmetric dimer eigenmodes is observed in white-light scattering experiments.

Besides providing evidence for atomic-scale gap modes at visible wavelengths with correspondingly small mode volumes, our experimental results can serve as a benchmark for electromagnetic modeling beyond local Maxwell theory.

O 85.6 Fri 11:45 MA 005

Quantum mechanic effects in nanoantenna enhanced infrared spectroscopy — •Jörg Bochterle, Frank Neubrech, and Annemarie Pucci — Kirchhoff-Institute for Phyiscs, Heidelberg, Germany

When light interacts with the conduction electrons of metal nanoparticles, the thereby resonantly excited localized surface plasmon resonance (LSPR) gives rise to a local field enhancement in the vicinity of the particles. Since the resonance frequency is governed by the geometrical shape of the particle, it can be tuned over a large spectral range. The strong fields are of great interest for sensing applications e.g. the detection of molecules by their vibrational fingerprint in the infrared. To measure the signal enhancement as a function of very small distances from the surface, we cooled a gold nanoantenna array on silicon substrate under ultra high vacuum conditions with liquid helium and adsorbed carbon monoxide (CO) gas. The enhanced signal of the CO stretching vibration is shown as a function of the layer thickness. Interestingly, the measurements differ from the classically expected behavior of a monotonically increasing near field towards the surface of the nanoparticle. However, describing the localized plasmon resonance quantum mechanically, the near field exhibits such monotonic increase only down to a certain distance and then decreases for smaller distances to the surface.

O 85.7 Fri 12:00 MA 005

Detecting low concentrations of pollutant chemicals in water by SERS:Combining optimised nanoparticle ensembles and SERDS — •R. Ossig[1], Y.-H. Kwon[2,3], H.D. Kronfeldt[2], and F. Hubenthal[1] — [1]Institut für Physik and CINSaT, Universität Kassel, Germany — [2]Technische Universität Berlin, Institut für Optik und Atomare Physik, Germany — [3]Institute of Lasers, Academy of Sciences, Unjong District, Pyongyang, DPR Korea

We present recently performed surface enhanced Raman spectroscopy (SERS) measurements using the combination of optimised silver nanoparticle (NP) ensembles and shifted excitation Raman difference spectroscopy (SERDS) to perform trace analysis of pollutant chemicals in water. The silver NPs were prepared under ultrahigh vacuum conditions on quartz substrates. The microsystem diode laser used is capable to generate two slightly different emission wavelengths ($\Delta\lambda \approx 0.5$ nm) with a spectral width of ≈ 10 pm, which is ideal for SERDS. To tune the surface plasmon resonance frequency of the NP ensembles in the vicinity of the excitation wavelength of the used diode laser, the morphology of the NPs was varied to obtain the optimal values for the investigated molecule-excitation wavelength combination. In this contribution we demonstrate, that optimising the optical properties of the silver NPs is essential for the detection of low pollutant concentrations. While for plasmon resonances in the vicinity of the excitation wavelength a low limit of detection in the order of 2 μm/l, is obtained, slightly off resonance NP ensembles yield a limit of detection that is at least 10 times higher.

O 85.8 Fri 12:15 MA 005

Plasmonic excitations in quasi 1d structures — •Ulrich Krieg, Christian Brand, Viktoria Meier, Herbert Pfnür, and Christoph Tegenkamp — Institut für Festkörperphysik, Leibniz Universität Hannover, Appelstrasse 2, D-30167 Hannover, Germany

A quasi one dimensional system was prepared by adsorption of 0.5 Ml Ag on vicinal Si (557) via self assembly. The morphology of these single domain wire like structures was characterised by spot profile analysis LEED (SPA-LEED), STM and subsequently studied by electron energy loss spectroscopy. For the latter an instrument with both high energy and momentum resolution was used (ELS-LEED). The measured loss spectra showed a strong anisotropy: In parallel direction the plasmonic loss dispersed linearly while in perpendicular direction the plasmonic loss does not disperse at all. This can be interpreted as an electronic decoupling and subsequently a confinement of the plasmon to the nanowires of finite width.

The quantitative simulation of the plasmonic losses in the low momentum regime is compatible with a wire width of 2.5 nm which agrees well with the width of the (111) terraces of Si (557). Indeed we found with SPA-LEED and STM the overall step-structure unchanged and the step-edges undecorated after the evaporation and annealing process. This confirms the model of a quantum well perpendicular to the nanowires used in our simulations.

O 85.9 Fri 12:30 MA 005

Radiative cooling of nanoparticles close to a surface — •Maria Tschikin and Svend-Age Biehs — Institut für Physik, Carl von Ossietzky Universität Oldenburg, D-26111 Oldenburg

In the present work we investigate the radiative cooling of a heated nanoparticle immersed in a thermal bath close to a partially reflecting surface. In the long-wavelength limit the particle can be considered as a simple dipole that radiates like an antenna. The radiated power of the dipole with a given temperature is then found within the framework of fluctuating electrodynamics. It turns out that the radiated power of the particle is not only proportional to its polarizability but also to the electric and magnetic local density of states. Hence, the radiated power which will determine the thermal relaxation time of the nanoparticle is very sensitive to its environment similar to the lifetime of an excited atom. Now, in our calculations we first introduce a thermal relaxation time τ and compare the results for a metallic and a polar nanoparticle. We demonstrate an oscillating behavior of τ with respect to the separation distance from the surface, an analog of Friedel oscillations in Fermi liquids. In addition it can be shown, that the cooling rate strongly depends not only on the temperature difference between particle and environment, but also on the absolute temperature of the environment.

O 85.10 Fri 12:45 MA 005

Spectral Shifts in Optical Nanoantenna-Enhanced Hydrogen Sensors — •Andreas Tittl[1], Christian Kremers[2], Jens Dorfmüller[1], Dmitry Chigrin[2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCoPE, University of Stuttgart — [2]Institute of High-Frequency and Communication Technology, Faculty of Electrical, Information and Media Engineering, University of Wuppertal

We present numerical investigations on the nature of spectral shifts in antenna-enhanced hydrogen sensing geometries consisting of a single gold bowtie antenna situated next to a palladium nanodisk.

We performed extensive numerical FEM calculations and will show how previously published experimental results for this system[1] can be modeled and understood by considering two competing effects: a small spectral blueshift of the resonance caused by the change of the dielectric function from Pd to PdH and a substantial redshift caused by the expansion of the Pd lattice and in turn of the Pd nanodisk.

The insight we gain into the spectral behavior of this system enables us to accurately model antenna-enhanced hydrogen sensors. Furthermore, it allows a numerical characterization and optimization of such structures beyond half bowtie geometries and thus paves the way towards the realization of extremely sensitive plasmonic hydrogen sensors.

[1] Liu et al., Nat. Mater. **10**, 631-636 (2011)