O 64: Plasmonics and nanooptics III

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

O 64.1 Thu 10:30 MA 005

Antenna-enhanced Photocurrent Microscopy on Single-Walled Carbon Nanotubes — •Nina Rauhut[1], Nitin Saxena[1], Michael Engel[2], Ralph Krupke[2], Mathias Steiner[3], and Achim Hartschuh[1] — [1]Department Chemie und CeNS, LMU, München, Germany — [2]Karlsruher Institut für Technologie, Karlsruhe, Germany — [3]T. J. Watson Research Center, IBM, Yorktown Heights, NY,USA

The unique optical and electronic properties of single-walled carbon nanotubes (SWCNTs) make these quasi 1D structures promising building blocks for nanoscale electronic and optoelectronic devices [1]. A powerful method to characterize SWCNT based field-effect transistors is scanning photocurrent microscopy (SPCM), where a focused laser spot is raster scanned across a device, recording the photocurrent signal at the same time. Due to diffraction SPCM measurements have been restricted so far to a spatial resolution of few hundred of nanometers.

We report on the first photocurrent measurements along single SWCNTs with sub 30 nm spatial resolution. Our approach extends conventional tip-enhanced near-field optical microscopy (TENOM) in which the diffraction limit is overcome by exploiting antenna-enhanced localized fields [2]. Combining SPCM and TENOM, we succeeded in simultaneously recording enhanced optical and photocurrent images with nanoscale resolution providing new insight into the optoelectronic properties of nanostructures.

[1] Avouris, P.; Chen, Z.; Perebeinos, V. Nat. Nanotechnol. 2007, 2, 605 [2] Hartschuh, A. Angew. Chemie (Int. Edition) 2008, 47, 8178

O 64.2 Thu 10:45 MA 005

Near-Field Investigation of Nanostructures with Normal Incidence Photoemission Electron Microscopy — •Pascal Melchior[1], Ernst Jan Vesseur[2], Alexander Fischer[1], Markus Rollinger[1], Daniela Bayer[1], Christian Schneider[1], Albert Polman[2], and Martin Aeschlimann[1] — [1]Fachbereich Physik and Research Center OPTIMAS, Technische Universität Kaiserslautern, Germany — [2]FOM Institute AMOLF, Amsterdam, The Netherlands

Photoemission electron microscopy (PEEM) enables the mapping of the near-field distribution of nanostructures under broadband laser excitation with a subwavelength spatial resolution. The combination with ultrafast laser pulses makes PEEM to an excellent technique to address the electron dynamics of nanoantennas by means of nonlinear photoemission. In standard PEEM systems, a grazing angle of incidence is used for illumination. However, the asymmetric illumination causes phase retardation effects and complex intensity distributions because of the superposition of higher order plasmonic modes. The complexity of the observed photoemission behavior under grazing angle makes the interpretation of static near-field distributions as well as time-resolved measurements challenging. With a new PEEM configuration we now excite the sample under normal-incidence and are thus able to eliminate these effects. We show first results of phase-resolved normal-incidence (NI) measurements on gold ring resonators that enable us to distinguish the resonance behavior of individual nanostructures with a subwavelength spatial resolution. The results are corroborated with FDTD calculations of the near-field properties of the structures.

O 64.3 Thu 11:00 MA 005

Time resolved near-field microscopy of metal nanoparticles — •Matthias Brandstetter[1,2], Ralf Vogelgesang[1], and Markus Lippitz[1,2] — [1]Max-Planck Institut für Festkörperforschung, Stuttgart — [2]4. Physikalisches Institut, Universität Stuttgart

The localized surface plasmon resonance (LSPR) of a metal nanoparticle depends directly on the geometry and the dielectric constant of the nanoobject. Impulsive heating through a laser pulse periodically modulates the geometry of a nanoparticle. The mechanical oscillations launched by the laser pulse lead to a variation in the local electron density of the nanoparticle and therefore a local variation in the dielectric properties. Using an AFM tip as near-field scatterer, we locally detect these changes of the dielectric properties of a nanoparticle on the nanoscale. The confinement of the near-fields will allow us to explore the elastomechanical properties of nanoparticles with a spatial resolution of 20nm. We present our combination of an apertureless scanning near-field microscope and a pump probe setup as well as first experimental results.

O 64.4 Thu 11:15 MA 005

Light Emission Mediated By A Lifted Conjugated Polymer — •Jingcheng Li[1], Gunnar Schulze[1], Luz M. Ballesteros[2], Anna Strozecka[1], Robin Schürmann[1], Katharina J. Franke[1], and Jose I. Pascual[1] — [1]Institut für Experimentalphysik, Freie Universität Berlin, Arnimallee 14, D-14195 Berlin, Germany — [2]Departamento de Química Física, Facultad de Ciencias, Universidad de Zaragoza, 50009 Spain

In molecular junctions, the coupling between transporting electrons and molecular vibrations can lead to molecular heating. Understanding and controlling the heat generation and dissipation are essential for future molecular electronics. In this project, combined with scanning tunneling microscope (STM) light emission, we explored the mechanism of molecular heating in the junction. The STM tip was used to contact a single conjugated polymer and lift it from surface to form molecular junction. Light emission induced by tunneling electrons through the molecular junction was collected. After removing the plasmon background, the strong coupling between electrons and molecular vibrations is uncovered. Black body radiation theory is used to determine the temperature of polymer chains.

O 64.5 Thu 11:30 MA 005

Magic Angles in Metamaterials — •Sven M. Hein[1], Lutz Langguth[1,2], and Harald Giessen[1] — [1]4th Physics Institute and Research Center SCOPE, University of Stuttgart, D-70569 Stuttgart, Germany — [2]Center for Nanophotonics, FOM Institute for Atomic and Molecular Physics (AMOLF), Science Park 104, 1098 XG Amsterdam, The Netherlands

When coupling two dipoles to each other in three dimensions, there are certain conditions under which the interaction vanishes. This effect is known for example in Nuclear Magnetic Resonance as "Magic Angles". It arises from the fact that at certain geometric arrangements the dipole coupling changes from attractive to repulsive. In 3D metamaterials [1], we have to consider the electric as well as the magnetic dipoles, and beyond spatial variation also twisting is possible, e.g. in stereometamaterials [2]. We investigate this intriguing effect in detail and show that it could be useful to elucidate quadrupole- and higher-order interactions. Allowing for retardation leads to a plethora of fascinating new effects.

[1] N. Liu et al., Nature Materials 7, 31 (2008).
[2] N. Liu and H. Giessen, Nature Photonics 3, 157-162 (2009).

O 64.6 Thu 11:45 MA 005

Near-field infrared microscopy with a broadband light source — •Stefanie Bensmann[1], Christoph Janzen[1], Reinhard Noll[1], and Thomas Taubner[1,2] — [1]Fraunhofer-Institut für Lasertechnik (ILT), Aachen — [2]1. Physikalisches Institut 1A, RWTH Aachen

Scattering-type near-field infrared microscopy (s-SNOM) allows to record IR spectra at a wavelength-independent spatial resolution of approx. 30 nm. In general these spectra are taken sequentially by repeating a measurement at different wavelengths which can be time-consuming. Furthermore, conventional MIR laser sources have a limited spectral range excluding the possibility to examine samples like e.g. certain semiconductors, polar crystals and different polymers.

These problems can be circumvented by using broadband IR light sources covering an extended frequency range. They allow to record a full spectrum within a single measurement (interferogram with Fourier transformation) [1-3]. However, thermal sources or a laser power of less than 1 mW only permit the study of samples with a strong resonance. We present first spectra recorded with a broadband IR laser with a power of several milliwatt at 8.9-13.7 μm that is currently developed at the ILT with the NeaSNOM (near-field optical microscope from Neaspec, www2.neaspec.com). This new system will extend the spectral range covered and allow to examine samples with weaker resonances.

[1] M. Brehm et al., Optics Express 15, p. 11222, 2006.
[2] S. Amarie et al., Optics Express 17, p. 21794, 2009.
[3] F. Huth et al., Nature Materials 10, p. 352, 2011.

O 64.7 Thu 12:00 MA 005

Quantitative analysis and modeling of the near-field optical signals on vertically layered samples — •Benedikt Hauer, Andreas Engelhardt, and Thomas Taubner — I. Institute of Physics (IA), RWTH Aachen University, Sommerfeldstraße 14, 52074 Aachen, Germany

In scattering-type scanning near-field optical microscopy (s-SNOM) the evanescent electric fields at the apex of a sharp illuminated tip can be used to probe the dielectric properties of a sample with a subwavelength resolution given by the tip radius. The near-field coupling depends on both the three-dimensional composition of the sample and the tip's material and geometry.

We present a quantitative and fully analytical theory to predict the s-SNOM signal strength of layered sample systems depending on the vertical tip–sample separation. The calculation is based on the well-established contrast model by Cvitković et al. [1] and coincides much better with experimental approach curves than a multilayer model in which the tip is approximated as a point dipole [2]. By varying the layer thickness and the imaging parameters we demonstrate the validity of our theory in the infrared spectral range. The findings are used to determine the optimum microscope settings in order to distinguish small differences in layer thickness or dielectric properties. Our work demonstrates the capability of s-SNOM to extract quantitative information on the vertical structure of a sample up to a depth of 100 nm.

[1] A. Cvitković et al., Optics Express 15, 8550 (2007)
[2] J. Aizpurua et al., Optics Express 16, 1529 (2008)

O 64.8 Thu 12:15 MA 005

Near-field Spectroscopic Imaging with Parabolic Mirror Assisted Gap-Mode Optical Microscopy — •Kai Braun, Dai Zhang, Xiao Wang, and Alfred J. Meixner — Institut für Physikalische und Theoretische Chemie, Universität Tuebingen, Germany

The recognition and identification of individual components is essential in many scientific issues. Raman microscopy is well established to detect chemical contrasts, however with a diffraction limited resolution. In this work we will present our recent work of high-resolution spectroscopic imaging using parabolic mirror assited gap-mode optical microscopy. A high NA parabolic mirror has been adopted in this new type of microscope as focusing and collecting element [1] which enables to investigate opaque samples with the highest NA achievable in air. Optical field enhancement is achieved in the gap between a sharp Au-tip and the substrate. The tip is excited efficiently by a radially polarized laser beam [2]. The optical signal emerging from the gap is simultaneously collected by an avalanche photo diode and a spectrometer. In addition the simultaneously obtained topographic information can be used for analysing the morphology correlated local material distribution We will show topographic and spectroscopic imaging of different components in a modified Diamond like Carbon (DLC) film etc. We demonstrate the prospective application of this microscope in a variety of important fields.

[1] M. A. Lieb, A. J. Meixner, Opt. Exp. 2001, 8, 456. [2] D. Zhang et all. PRL, 2010, 104, 5.

O 64.9 Thu 12:30 MA 005

Phase-sensitive near-field mapping — •Stefan Griesing, Andreas Englisch, and Uwe Hartmann — Institute of Experimental Physics, Universität des Saarlandes, P.O. Box 15 11 50, D-66041 Saarbrücken

The combination of a standard SNOM set-up with an interferometer give an access to the phase information of the optical near-field. Fiber-based aperture SNOMs connected to a pseudoheterodyne setup are sensitive to low-frequency phase variations which are caused by environmental effects. In order to stabilize the reference phase, we introduced an active phase stabilization system in our setup. The detected near-field signal is demodulated by a lock-in amplifier. The real part of the second harmonic of the fiberstretchers drive frequency is detected and used as input signal for a PID feedback loop. The stretcher is then driven by a signal composed of the modulation part and the feedback part. In the case of a slow PID loop which solely follows the environmentally caused phase fluctuations, amplitude and phase information of the sample are obtained by demodulation of the first harmonic. The most interesting application is the investigation of highly dispersive media. In this case, a second wavelength is injected in the system. The PID feedback loop is fed with the real part of the second harmonic of one wavelength as described above. If a short time constant of the feedback-loop is chosen it becomes fast and compensates completely for phase variations of the input wavelength. Solely the difference phase of both wavelengths, caused by the dispersion of the sample, remains in the interference signal and can be measured.

O 64.10 Thu 12:45 MA 005

Investigation of mid-infrared s-SNOM subsurface imaging on topography-free samples — •Andreas Engelhardt, Benedikt Hauer, and Thomas Taubner — I. Institute of Physics (IA), RWTH Aachen University, Sommerfeldstraße 14, 52074 Aachen, Germany

Scattering-type scanning near-field optical microscopy (s-SNOM) provides optical information of a sample with a nanoscale-resolution in the order of the probing tip radius (~ 30 nm) which allows for material-specific imaging and even spectroscopy on the nanoscale. Optical coupling of the probe with nanoscale objects also occurs through thin cover layers of low refracting materials enabling the detection of objects underneath the surface [1].

We demonstrate subsurface s-SNOM imaging of metallic nanostructures with mid-infrared light through thin ($30 - 100$ nm) and flat dielectric layers. The latter do not reveal the geometry of the structures in their surface topography, thus topography artifacts are avoided. We observe that the visibility of the buried objects improves with increasing oscillation amplitude of the probe due to a better signal-to-noise ratio, however at the cost of contrast loss. The study provides basic experimental data for the theoretical development of a powerful s-SNOM based nondestructive nano-tomography characterization method [2].

[1] T. Taubner *et al.*, Optics Express, **13**, 8893 (2005)
[2] J. Sun *et al*, APL, **95**, 121108 (2009)