O 29: Near-Field Microscopy

Time: Tuesday 14:00–16:00 Location: MA 042

O 29.1 Tue 14:00 MA 042

$\lambda/30$ Lateral Resolution in Subsurface Imaging with an Infrared Near-Field Microscope — •Lena Jung, Benedikt Hauer, and Thomas Taubner — I. Institute of Physics (IA), RWTH Aachen University, 52056 Aachen, Germany

In scattering-type scanning near-field optical microscopy (s-SNOM), optical near-fields at the apex of a sharp illuminated tip are used for an investigation of the optical properties of the sample material with high spatial resolution. Since near-fields penetrate into a dielectric sample, non-destructive imaging of subsurface structures under thin layers of dielectrics is possible [1]. This capability provides a useful tool in the field of nanotechnologies, since nano-electronic devices are often covered by thin dielectric capping layers such as e.g. SiO_2 or Si_3N_4.

The visibility of gold nanoparticles under a Si_3N_4-membrane in dependence of its thickness is investigated as well as the lateral resolution and signal contrast for different sizes of particles. A comparison to transmission electron microscopy (TEM) images of the same sample region enables a direct correlation between the nanostructures and the optical signals. The experimental results are confirmed by model calculations.

A spectroscopic investigation reveals a significant change in the lateral resolution due to the actual value of the dielectric function. Achievable is a resolution down to $\lambda/30$ for mid-infrared light. We observe minima at specific wavelengths and correlate these to the optical properties of the capping material and the so called superlensing effect.

[1] Taubner et al., Opt. Express 13, 8893 (2005).

O 29.2 Tue 14:15 MA 042

New Directions in Tip-Enhanced Near-Field Optical Microscopy — •Julia Janik, Nina Mauser, and Achim Hartschuh — Department Chemie and CeNS, LMU München, Germany

The characterisation of nanostructures with high spatial resolution and detection sensitivity can be achieved by tip-enhanced near-field optical microscopy (TENOM)[1]. We report on our efforts to extend this method into further directions. One direction is the application of tip-enhancement to photovoltaic and light-emitting devices as suggested in [2]. We obtained the first high-resolution photocurrent images of carbon nanotube devices using a metal tip to locally enhance optical-to-electrical transduction [3]. We show that the efficiency of the reversed process leading to electroluminescence can be increased as well. We also implemented tip-enhanced near-field optical microscopy at low temperatures (~5 K) and present a new microscope design based on a solid immersion lens configuration providing very high collection angles and efficiencies.

We acknowledge Financial support by DFG, NIM and the ERC (New- NanoSpec).

[1] N. Mauser, A. Hartschuh, Tip-enhanced near-field optical microscopy, Chem. Soc. Rev. 43, 1248 (2014).

[2] P. Bharadwaj, B. Deutsch, L. Novotny, Optical Antennas, Adv. Opt. Photon. 1, 438 (2009).

[3] N. Mauser et al., Antenna-Enhanced Optoelectronic Probing of Carbon Nanotubes, Nano. Lett. 14, 3773 (2014).

O 29.3 Tue 14:30 MA 042

Excitation power dependence in tip-enhanced Raman spectroscopy — •Tobia Mancabelli, Xian Shi, and Achim Hartschuh — Department Chemie & CENS, Ludwig-Maximilians-University, Munich, Germany

Tip Enhanced Raman Spectroscopy (TERS) exploits the enhanced electric field in the proximity of an optical antenna to achieve nanometer spatial resolution and high detection sensitivity [1]. A recent report indicates a contribution of nonlinear Raman scattering in the case of extremely strong enhancement achieved within the nanogap formed by a silver tip on a silver substrate [2]. Recently, a new mechanism contributing to surface-enhanced Raman scattering based on dynamical backaction has been proposed [3]. We conducted power-dependent confocal and tip-enhanced measurements of the Raman G-band intensity of single carbon nanotubes deposited on different substrates to reveal possible contribution from stimulated Raman scattering and dynamical backaction. Financial support by the ERC (NEWNANOSPEC) and the DFG through the Nanosystems Initiative Munich (NIM) is gratefully acknowledged. [1] MAUSER N., HARTSCHUH A.; CHEM. SOC. REV.; 43, 1248, 2014. [2] ZAHNG R. ET AL.; NATURE 82, 498, 2013. [3] ROELLI P. ET AL.; ArXiv: 1407.1518v1 (2014).

O 29.4 Tue 14:45 MA 042

Gap mode formation in metallic, nanofocusing SNOM tapers — •Simon F. Becker[1], Martin Esmann[1], Kyungwan Yoo[1,3], Petra Gross[1,2], Ralf Vogelgesang[1], Namkyoo Park[3], and Christoph Lienau[1] — [1]Carl von Ossietzky Universität, 26111 Oldenburg, Germany — [2]Universität Osnabrück, 49076 Osnabrück, Germany — [3]Seoul National University, Seoul, Korea

Surface plasmon polaritons (SPPs) propagating on metallic tapers get nanofocused at the apex. This largely reduces unwanted background contributions in apertureless scanning near-field optical microscopy (SNOM) [1,2] and provides direct access to broadband nanospectroscopy.

Here, we analyze the near-field formation at the apex of single crystalline gold tapers by using them as SNOM probes [3]. We investigate the imaging mechanism in scattering geometry and in the Fourier domain. The experimental results are compared to detailed finite element method (FEM) simulations. In particular, we find strong evidence for the formation of a gap mode between probe and sample, both in the experiment and the simulation. The results indicate that this spectrally broadband interaction is extremely short-ranged and has the potential to enhance the spectroscopic imaging resolution down to the single nanometer regime.

[1] M.I. Stockman, PRL 93, 137404 (2004); [2] S. Schmidt et al., ACS Nano 6, 6040 (2012); [3] M. Esmann et al., BJ Nano 4, 603 (2013).

O 29.5 Tue 15:00 MA 042

Broadband nanospectroscopy with metallic, nanofocusing SNOM tapers — •Martin Esmann[1], Simon F. Becker[1], Heiko Kollmann[1], Petra Gross[1,2], Ralf Vogelgesang[1], and Christoph Lienau[1] — [1]Carl von Ossietzky Universität, 26111 Oldenburg, Germany — [2]Universität Osnabrück, 49076 Osnabrück, Germany

Broadband extinction spectroscopy with nanoscale lateral resolution demands methods with low background signals. To this end, a very promising approach is the concept of adiabatic nanofocusing in metallic nanotapers[1,2]. Surface plasmon polaritons (SPPs) are excited on a grating coupler and result in strongly confined near-fields at the taper apex.

Here, we use single crystalline gold tapers as scanning near-field optical microscopy (SNOM) probes[3] in combination with broadband white-light excitation. We test this approach by imaging the spectrally dependent near-field enhancement over a planar gold film. On this basis, we perform extinction spectroscopy on individual nanoantennas with a spectral bandwidth of several hundreds of nanometers. The very high lateral resolution of our approach allows us to spectrally image the mode profiles of such individual nanostructures. In combination with ultrashort pulses this method can be straightforwardly extended to the investigation of coherences in quantum and biological systems.

[1] M.I. Stockman, PRL 93, 137404 (2004); [2] S. Schmidt et al., ACS Nano 6, 6040 (2012); [3] M. Esmann et al., BJ Nano 4, 603 (2013).

O 29.6 Tue 15:15 MA 042

Analysis of light depolarization in near-field apertureless optical techniques — •Evgeniya Sheremet, Vladimir Kolchuzhin, Raul D. Rodriguez, Jan Mehner, Dietrich R.T. Zahn, and Michael Hietschold — Technische Universität Chemnitz, Chemnitz, Germany

Apertureless near-field methods mostly rely on localized surface plasmons generated at the apex of gold or silver tips under illumination. This allows the spatial resolution of near-field optical microscopy and spectroscopies to be decreased from hundreds of nanometers to the sub-10 nm scale. The near-field has a different polarization from that of the incident field due to the presence of the tip. This can lead to loss of information about inherent selection rules of the sample, or used to our benefit for separating the near-field signal from the far-field contribution. Here, we analyze the polarization of the enhanced field on the tip apex using finite element method. The simulations are performed for tips with apex radii from 10 to 50 nm in free space placed above dielectric or metallic surfaces, or without substrate. We find that a gold tip placed above a gold substrate efficiently rotates the incident field of any polarization along the tip axis. The same tip in air shows a homogeneous distribution of the field components polarized along different directions thus depolarizing the incident field regardless of its polarization. The simulations also show a drastic improvement in spatial resolution for a tip above a gold substrate as compared to the tip in air. These results demonstrate the importance of the substrate nature in near-field optical techniques.

O 29.7 Tue 15:30 MA 042

Low-temperature scattering scanning near-field optical microscopy — •Jonathan Döring, Kehr Susanne C., and Eng Lukas M. — IAPP, Technische Universität Dresden

We present a fully operating low-temperature scattering scanning near-field optical microscope (LT-s-SNOM) with access to a tunable free-electron laser (FEL) source. The light scattered off an AFM tip strongly depends on the tip-sample near-field interaction, and thus enables mapping of optical properties with a resolution several orders of magnitude below the diffraction limit. The FEL provides spectrally narrow laser radiation in the regime from 4 to 250 μm at a high power density. By the novel and unique combination of LT-s-SNOM and FEL, optical properties of materials can be measured at specific wavelengths as well as at temperatures down to $4\,K$. Our device is therefore perfectly suited for investigating phase transitions of sample materials featuring phonon resonances in the mid-to-far-infrared regime.

We present measurements of ferroelectric phase transitions of barium titanate (BTO). We use this unique setup to investigate the two ferroelectric phase transitions of barium titanate single crystals below room temperature at $253\,K$ and $173\,K$. The first constitutes a structural phase transition from tetragonal to orthorhombic, which reflects in both a different domain arrangement and significant phonon resonance shifts, as probed near-field optically [1]. The second transition changes the pattern to rhombohedral, again reflected in both altered micrographs and spectra.

[1] Döring et al., Appl. Phys. Lett. 105, 053109 (2014)

O 29.8 Tue 15:45 MA 042

Adapting ultra-broadband Synchrotron Radiation Sources for nano-FTIR Spectroscopy — •Peter Hermann[1], Arne Hoehl[1], Bernd Kästner[1], Piotr Patoka[2], Georg Ulrich[2], Jörg Feikes[3], Markus Ries[3], Tobias Goetsch[3], Godehard Wüstefeld[3], Burkhard Beckhoff[1], Eckart Rühl[2], and Gerhard Ulm[1] — [1]Physikalisch-Technische Bundesanstalt (PTB), Abbestraße 2-12, 10587 Berlin — [2]Physikalische und Theoretische Chemie, Institut für Chemie und Biochemie, Freie Universität Berlin, Takustraße 3, 14195 Berlin — [3]Helmholtz-Zentrum Berlin (HZB), Albert-Einstein-Straße 15, 12489 Berlin

Near-field techniques such as infrared scanning near-field optical microscopy and nano-FTIR spectroscopy enable imaging and spectroscopic characterization of samples at the nanoscale. While for near-field imaging typically monochromatic light sources are required to map the chemical composition of the sample surface, near-field infrared spectroscopy requires sources with a broad emission spectrum. Successful nano-FTIR experiments utilizing ultra-broadband synchrotron radiation have been recently demonstrated by several groups. In order to exploit the full potential of this approach we report on the adaption of storage ring optics at the Metrology Light Source (MLS) reducing the size of the electron bunches in order to improve the spatial coherence of synchrotron radiation. In combination with appropriate spectral filters the sensitivity of synchrotron-based near-field spectroscopy can be increased significantly, thus enabling also the spectroscopic characterization of thin organic layers.