Q 64: Nano-Optics III

Time: Friday 10:30–12:30 Location: Q-H11

Q 64.1 Fri 10:30 Q-H11

Extinction spectroscopy of ellipsoidal nanoparticles — •Mathis Noell and Carsten Henkel — Universität Potsdam, Institut für Physik und Astronomie

Plasmonic nanostructures provide an interesting platform to enhance the spectroscopy of molecules. If a nanoparticle is covered with a thin absorbing layer, theory predicts certain resonances that are not seen in experimental extinction spectra [1, 2]. To understand this issue, we analyse the distribution of electric fields and of energy dissipation in and around an ellipsoidal nanoparticle. Calculations are done for gold particles covered with a few nm thick layer. At the spurious resonance, the field is highly localised in this layer, suggesting that strong coupling to the molecular exciton is possible at the few-photon level. We compare the impact of different effective medium approaches on the calculated spectra.

[1] F. Stete et al., "Vacuum Induced Saturation in Plasmonic Nanoparticles," arXiv:2008.09395.

[2] T. J. Antosiewicz, S. P. Apell, and T. Shegai, "Plasmon–Exciton Interactions in a Core–Shell Geometry: From Enhanced Absorption to Strong Coupling," ACS Photonics **1**, 454 (2014).

Q 64.2 Fri 10:45 Q-H11

Theory of radial oscillations in metal nanoparticles driven by optically induced electron density gradients — •Robert Salzwedel[1], Andreas Knorr[1], Dominik Hoeing[2], Holger Lange[2], and Malte Selig[1] — [1]Institut für Theoretische Physik, Nichtlineare Optik und Quantenelektronik, Technische Universität Berlin, Berlin, Germany — [2]The Hamburg Centre for Ultrafast Imaging, Hamburg, Germany

Radial breathing modes can be excited in metallic nanoparticles by optical excitations. In current classical theory, these oscillations are thought to be driven by the thermalization of hot electrons, which impulsively heat the lattice [1,2]. We provide a quantum hydrodynamic theoretical approach for the optical excitation of the electron gas in metal nanoparticles and the associated electron-phonon interaction.

We find that the ultrafast dynamics of electron occupation and the coherent phonon amplitude are responsible for the size oscillations of the nanoparticle. The optical excitation induces spatial gradients in the electron density that directly drive coherent phonon oscillations. Therefore, our results show a more direct coupling mechanism between the field and phonons compared to the established interpretation of experiments [3,4], and it is shown that thermalization is of reduced importance in the early stages of the oscillation.

[1] Hartland, G. V. et al., JCP, 116, 8048 (2002)
[2] Hodak, J. H. et al., JCP, 111, 8613 (1999)
[3] Del Fatti, N. et al., JCP, 110, 11484 (1999)
[4] Ng, M. Y. et al., JCP, 134, 094116 (2011)

Q 64.3 Fri 11:00 Q-H11

Room-temperature strong coupling of a single quantum dot to a tunable plasmonic nanogap antenna using a novel scanning probe technique — •Michael A. Becker[1], Hsuan-Wei Liu[1], Korenobu Matzusaki[1], Randhir Kumar[1], Stephan Götzinger[2,1], and Vahid Sandoghdar[1,2] — [1]Max Planck Institute for the Science of Light, Erlangen, Germany — [2]Department of Physics, Friedrich-Alexander University of Erlangen-Nürnberg, Erlangen, Germany

Scanning probe techniques offer a workhorse for optical investigations of structures smaller than the diffraction limit. In particular, scanning near-field optical microscopy (SNOM) can be used to probe light-matter interactions at the nanometer scale. However, the mechanical stability of the tip and its nanometric distance to the sample pose severe challenges for routine and robust measurements. Here, we report on a novel and simple tip-free scanning probe technique capable of carrying out high-precision near-field optical studies on single emitters. We utilize this technique to create an open and tunable nanogap antenna that can be tuned in resonance with the exciton transition of a single semiconductor quantum dot. With nanometer precision and a remarkable mechanical stability, the single emitter is positioned at the antenna hotspot, tuning the system between the weak and strong light-matter coupling regimes. We present spectral splitting and a characteristic anticrossing behavior.

Q 64.4 Fri 11:15 Q-H11

On the usage of fluorescent nanodiamonds in modern nanoscopy — •Philipp Kellner[1], Max Haase[1], Tanja Weil[3], and Christian Eggeling[1,2] — [1]Institut für angewandte Optik und Biophysik, Friedrich-Schiller-Universität, Philosophenweg 7, 07743 Jena — [2]Leibnitz-Institut für photonische Technologien, Albert-Einstein-Straße 9, 07745 Jena — [3]Max-Planck-Institut für Polymerchemie, Ackermannweg 10, 55128 Mainz

Fluorescent correlation spectroscopy (FCS) is a widely used microscopy-based, non-invasive technique for measuring mechanical and chemical properties like diffusion coefficient and concentration of specific molecules in solution, biological tissue and soft matter samples. This talk will present the basics of fluorescence correlation spectroscopy and newest insights in FCS in combination with modern Stimulated Emission Depletion (StED-) Nanoscopy using fluorescent nanodiamonds, a bright, stable, biocompatible nanoparticle as a probe. We will elaborate on the usage of the method, the nanoparticle and their combination for dynamical measurements on length-scales far below the diffraction limit. A special focus will be on the question: Are StED-FCS experiments biased by optical tweezer effects?

Q 64.5 Fri 11:30 Q-H11

Coincidence gated imaging using free electrons and photons — Armin Feist[1,2], Guanhao Huang[3], •Germaine Arend[1,2], Yujia Yang[3], Jan-Wilke Henke[1,2], Arslan Sajid Raja[3], F. Jasmin Kappert[1,2], Rui Ning Wang[3], Hugo Lourenco-Martins[1,2], Junqiu Liu[3], Ofer Kfir[1,2], Tobias J. Kippenberg[3], and Claus Ropers[1,2] — [1]Georg-August Universität Göttingen, Germany — [2]Max Planck Institute for Biophysical Chemistry, Göttingen, Germany — [3]Swiss Federal Institute of Technology, Lausanne, Switzerland

Electron microscopy can probe optical modes at the nanoscale with the light generated by a focused electron beam. In this the photonic density of states and optical transitions are mapped, while photon statistics reveal the properties and lifetime of excitations. However, current methods largely disregard correlated properties of the single electrons involved.

In this work, we demonstrate the generation of photons in a Si_3N_4 high-Q resonator and characterize their temporal and energetic correlation with the inelastically scattered electrons. We also show how photonic mode mapping using correlated events allows for a two-order of magnitude contrast enhancement for extremely low-intensity signals.

Q 64.6 Fri 11:45 Q-H11

Nanoscale Imaging of Live Cells with Confocal Interferometric Scattering (iSCAT) Microscopy — •David Albrecht[1], Michelle Küppers[1,3], Anna Kashkanova[1], Jennifer Lühr[1], and Vahid Sandoghdar[1,2,3] — [1]Max Planck Institute for the Science of Light, 91058 Erlangen, Germany — [2]Max-Planck-Zentrum für Physik und Medizin, 91058 Erlangen, Germany — [3]Friedrich-Alexander University Erlangen-Nürenberg, 91058 Erlangen, Germany

Light microscopy methods are widely used in biomedical research to investigate cellular structure and dynamics in live specimen. Label-free approaches are of particular interest to circumvent problems such as phototoxicity, functional impairment or insufficient signal that may be imposed by the label. Here, we present nanoscale imaging with confocal interferometric scattering (iSCAT) microscopy for recording label-free information from subcellular processes. iSCAT is a shot-noise limited homodyne interferometry technique, which has been extensively used for tracking nanoparticles with exquisite performance. However, application of iSCAT for cellular imaging has been hampered by a strong speckle-like background. By employing a pinhole in a confocal arrangement, we show that one can reject a large portion of the background scattering from the complex environment of a live cell. We, thus, identify cellular organelles and confirm our findings through the molecular specificity of concomitant fluorescence microscopy measurements. We also investigate the interaction of nanoscopic matter such as intracellular vesicles, lipid droplets and viruses in a cellular context at a high spatial and temporal resolution.

Q 64.7 Fri 12:00 Q-H11

Nanoscopic Charge Fluctuations in a Gallium Phosphide Waveguide Measured by Single Molecules — •Alexey

Shkarin[1], Dominik Rattenbacher[1,3], Jan Renger[1], Simon Hönl[2], Tobias Utikal[1], Paul Seidler[2], Stephan Götzinger[3,1], and Vahid Sandoghdar[1,3] — [1]Max Planck Institute for the Science of Light, D-91058 Erlangen, Germany — [2]IBM Research Europe, Säumerstrasse 4, CH-8803 Rüschlikon, Switzerland — [3]Department of Physics, Friedrich Alexander University Erlangen-Nuremberg, D-91058 Erlangen, German

Nanometer-scale electric field fluctuations can shed light on material properties of technological interest such as crystal defects and charge distributions. However, nanoscopic characterization of these features is challenging because there exist not many probes that combine the necessary sensitivity, size, and vicinity to the location of interest. In our work [1], we study local electric field fluctuations via the Stark shift induced in single quantum emitters. Specifically, we examine the field at several points directly next to a GaP waveguide (< 50 nm away) using individual dibenzoterrylene molecules embedded in para-dichlorobenzene as nanoscopic probes. We discuss a series of experiments for investigating the spatial and temporal correlations of the electric field to confirm that the observed fluctuations originate in GaP and are photoinduced. Furthermore, we analyze the statistics of the fluctuations and show that it is consistent with fluctuations being induced by very few (< 50) charges jumping under the influence of light.

[1] A. Shkarin et al., Phys. Rev. Lett. 126, 133602 (2021)

Q 64.8 Fri 12:15 Q-H11

Ultrafast Field Microscopy of Terahertz Near-field Waveforms — •Moritz B. Heindl[1], Nicholas Kirkwood[2], Tobias Lauster[3], Julia A. Lang[1], Markus Retsch[3], Paul Mulvaney[2], and Georg Herink[1] — [1]Experimental Physics VIII, University of Bayreuth, Germany — [2]ARC Centre of Excellence in Exciton Science, School of Chemistry, University of Melbourne, Australia — [3]Physical Chemistry I, University of Bayreuth, Germany

Access to high-frequency electric waveforms is critical to the understanding of ultrafast plasmonic and field-driven nonlinear phenomena, yet, microscopic measurements still present a grand challenge. Here, we present a fluorescence-based field microscope for imaging ultrafast THz near-field evolutions using quantum dots. The Quantum-probe Field Microscopy (QFIM) scheme is enabled by the quantum-confined Stark-effect encoding the local field evolution in the luminescence yield of semiconductor nanocrystals [1,2]. QFIM allows for the spatio-temporal detection of THz sub-wavelength fields in the optical far-field using conventional fluorescence microscopy. We demonstrate the spatio-temporal tracking of propagating wavepackets confined to sub-wavelength THz waveguides, and we investigate the near-field evolutions inside single THz antennas with sub-cycle resolution [3]. QFIM paves a new route towards in-operando nanoscopy of nonlinear interactions and ultrafast nanodevices.

[1] Hoffmann, M. C. et al. Appl. Phys. Lett. 97, 231108 (2010).
[2] Pein, B. C. et al. Nano Lett. 17, 5375-5380 (2017).
[3] Heindl, M. B. et al. Light Sci. Appl. (in press).