O 43: Poster: Plasmonics and Nanooptics I

Time: Tuesday 18:00–20:00 Location: P2/EG

O 43.1 Tue 18:00 P2/EG

Quantitative Modeling of Scattering-type Scanning Near-field Optical Microscope (s-SNOM) with the Finite Element Method Utilizing the Software JCMSuite — •Dinghe Dai, Dario Siebenkotten, Richard Ciesielski, and Bernd Kästner — Physikalisch-Technische Bundesanstalt, Abbestr. 2-12, 10587 Berlin

Scattering-type scanning near-field optical microscopy (s-SNOM), where local field enhancement is created with an oscillating nanotip, is widely applied in the nanoscale characterization of nanostructures, surface polaritons, and biomolecular systems. s-SNOM requires quantitative evaluation schemes with analytical models or simulation methods, among which the Finite Dipole Model [1] is a sophisticated model to calculate the near-field scattering for bulk materials. Nevertheless, it cannot model the full tip size or surface nanostructures. To solve this, a numerical model, based on the finite element method (FEM) software JCMSuite, is developed. The model describes the electromagnetic field over several orders of magnitude in physical size. At various infrared incident wavelengths (μm), the electromagnetic fields are simulated for different tip-sample gaps (nm) and demodulated at harmonics of the tapping frequency to eliminate background field effects. The agreement and deviation of amplitude and phase spectra between both models across multiple demodulation orders are discussed. The FEM by JCMSuite combined with field demodulation is a credible quantitative s-SNOM simulation method especially interesting for complex multilayer and nanooptical structures.

[1] Cvitkovic et al. Optics express 15(14) (2007): 8550-8565.

O 43.2 Tue 18:00 P2/EG

Switching nonlinear emission patterns of plasmonic nanostructures — •Valentin Dichtl, Kilian Wittman, Thorsten Schumacher, and Markus Lippitz — Experimental Physics III, University of Bayreuth, Germany

The nonlinear third-order material response of noble metals allows to shape the third-harmonic near field around a plasmonic nanostructure [1]. The corresponding spatial emission pattern of the third harmonic hot spots changes drastically when slightly tuning the fundamental wavelength over a linear resonance of the nanorod. This raises the question of whether similar behavior can be found for other nonlinear emission processes.

Here, we demonstrate by hyperspectral imaging that not only the third- but also the second-harmonic and especially the two- (or multi-) photon excited luminescence (TPPL) emission changes spatially, when tuning over the plasmon resonance. We discuss spatial and spectral differences between these processes.

The outlook is targeted towards selectively exciting single quantum emitters in the nearfield. As first step into this direction we present differences in the spatial change of luminescence of a dye film with respect to the underlying emission pattern.

[1] Wolf, D. *et al.* Shaping the nonlinear near field. *Nat. Commun.* 7:10361 (2016). doi: 10.1038/ncomms10361

O 43.3 Tue 18:00 P2/EG

Deep learning for the extraction of optical parameters of multilayer samples in scanning near-field optical microscopy — •Dario Siebenkotten, Lara Harren, Clemens Elster, and Bernd Kästner — Physikalisch-Technische Bundesanstalt, Abbestr. 2-12, 10587 Berlin

Scattering-type scanning near-field optical microscopy (s-SNOM) is a powerful method for optical material characterization at the nanoscale. However, owing to the complex interaction between tip and sample, extensive modelling is needed for the extraction of optical parameters, particularly for layered samples. The extraction of optical parameters typically requires fitting, which quickly becomes unstable [1] and can be very time intensive due to the complexity of the models. Deep Learning algorithms offer a fast alternative for the optical parameter extraction but have only been applied to bulk materials. Here, we show the extension of these approaches to systems consisting of one and two layers of polar crystals exhibiting surface phonon-polariton resonances on top of a substrate by training neural networks with model data. We present the trained neural networks and discuss the extraction accuracy for the cases of one and two layered samples. While this study is limited to polar crystals, the application to other systems, defined for example by free charge carriers or band transitions, is straight forward.

[1] McArdle et al. Phys. Rev. Research 2, 023272 (2020)

O 43.4 Tue 18:00 P2/EG

Nonlinear near-field optical microscopy (NNOM) for plasmonic skyrmions — •Florian Mangold, Bettina Frank, and Harald Giessen — 4th Physics Institute, Research Center SCoPE, and IQST, University of Stuttgart, Pfaffenwaldring 57, 70569 Stuttgart, Germany

In recent years, plasmonic skyrmions have become a growing field of research. The state-of-the-art detection is done with PEEM (photoemission electron microscopy) or SNOM (scanning near-field optical microscopy) measurements.

An alternative to these methods is nonlinear near-field optical microscopy (NNOM) which uses an optical nonlinear process to image evanescent waves on the sub-wavelength-scale and enables real-time imaging of surface waves. By combining information from real and Fourier-space images, it is possible to calculate the phase and the amplitude of all electric field components.

The NNOM setup will be used to complement PEEM and SNOM measurements and gives us additional possibilities to investigate topological features in plasmonics such as quasicrystals, skyrmions and skyrmion bags.

O 43.5 Tue 18:00 P2/EG

Greyscale lithography with photoresist for plasmonic coupling — •Julian Alin, Michael Seidel, Thorsten Schumacher, and Markus Lippitz — Experimental Physics III, University of Bayreuth, Germany

Integrated plasmonic nanocircuits promise to play a major role for future applications of quantum optical technologies. Therefore stable, bright and narrow-band single-photon sources are required, such as self assembled epitaxially grown GaAs quantum dots [1]. Crucial for the coupling of such a quantum dot to a waveguide is, that for a high efficiency the waveguide has to be placed close to the quantum dot. However, the spatial proximity to the surrounding semiconductor material with a high refractive index strongly attenuates the surface plasmon propagation. In order to solve this problem we try to create a structure where the waveguide will be close to the quantum dot, but far away from the semiconductor material (a few hundred nanometers). To achieve this trough-like structure the idea is to apply a photoresist on a GaAs-sample, write a trough with a focussed gaussian laser beam and place a waveguide at this position. We discuss experiments on such structures with waveguides on glass substrates and first steps on GaAs wafers.

[1]Wu et al., Nano Lett. 2017, 17, 7, 4291-4296

O 43.6 Tue 18:00 P2/EG

Resistive heating of monocrystalline plasmonic resonators — •Jacob Syndikus, Luka Zurak, Jessica Meier, Bert Hecht, and Thorsten Feichtner — Nanooptics & Biophotonics Group, Experimental Physics 5, RCCM, JMU Würzburg, Am Hubland, D-97074 Würzburg, Germany

Plasmonic resonators can focus light down to sub-diffraction-limited near-field intensity volumes by collective oscillations of photons and electrons. Therefore, they are hot candidates for electro-optical devices with minimal footprint, bridging the gap between fiber communication and electronics or even being optical switches by themselves. To achieve this, the plasmonic properties have to be actively tuned, the faster the better.

Here we show experimentally the modulation of the wavelength dependent scattering intensity by a gold nanorod in the MHz range by resistive heating. Application of an AC voltage heats the gold material by several tens of Kelvin, changing the electron energy density and with it the dielectric constant ε_{Au}. The small volume and the electrical contacts ensure fast heat dissipation. We fabricate the structures from monocrystalline goldflakes by means of Ga- and He-ion beam milling and measure the changes in the resonance curves via white light laser illumination and modelocking detection. Numerical models show that GHz modulation is feasible to be realized which makes the technique interesting for applications.

O 43.7 Tue 18:00 P2/EG

Electrochemistry of the surface of electrically contacted plasmonic resonators — •Paul Mörk, Luka Zurak, Jessica Meier, Bert Hecht, and Thorsten Feichtner — Nano-Optics & Biophotonics Group, Experimental Physics 5, University of Würzburg, Am Hubland, 97074 Würzburg, Germany

Catalytic processes on gold surfaces are well known to enhance electrochemical processes. When the gold is showing geometric features on the nanometer scale, plasmonic resonances in the visible wavelength range can occur. This establishes addidional degrees of freedom (photon routing, heating, hot electron generation) to tailor an efficient material for photo-electrochemical processes interesting for energy applications like water splitting or CO_2 reduction.

Here we show the results of experiments with directly electrically connected plasmonic resonantors made via focused ion beam milling from monocrystalline gold flakes. Under ambient conditions without any further chemical added we observe a resonance shift by several ten of nanometers on a time scale of seconds when applying a electrical potential as high as 20 Volts to the gold surface. The effect reverses when the bias voltage is switched of on the time scale of hours. We present evidence that we observe the electrochemical oxidation and reduction of gold mediated by the omnipresent waterlayer covering every surface with nanometer thickness and deliver an outlook to the application within electrochemical cells.

O 43.8 Tue 18:00 P2/EG

Exciton lifetime of decoupled phthalocyanine molecules — •Amandeep Sagwal[1,2], Jiří Doležal[1], Rodrigo Cezar De Campos Ferreira[1], Petr Kahan[1], and Martin Švec[1,3] — [1]Institute of Physics, Czech Academy of Sciences; Praha, Czech Republic — [2]Faculty of Mathematics and Physics, Charles University; Czech Republic — [3]Institute of Organic Chemistry and Biochemistry, Czech Academy of Sciences; Czech Republic

A few layers of NaCl decoupling layer on metal are sufficient to prevent the nonradiative quenching of the excited state in phthalocyanine [1] and observe fluorescence in the far field from the molecule located in the junction of a scanning tunneling microscope (STM). First attempts to measure the lifetimes of exciton in the nanocavity suggested lifetimes of hundreds of picoseconds [2,3] but later studies pointed towards a transient charge state lifetime involved in the electroluminescence excitation process [4,5] and estimated the lifetime to be several orders of magnitude lower, due to the Purcell effect of the plasmonic nanocavity. Here, we use a pulsed supercontinuum laser to reveal the radiative decay of the excited state of the molecules with and without the presence of nanocavity.

[1]*F. Aguilar-Galindo et al. ACS Photonics 8, 3495 (2021) [2]*L. Zhang et al. Nat. Commun. 8, 580 (2017). [3]*J. Doležal et al. ACS Nano 15, 7694 (2021). [4] B. Yang et al. Nat. Photonics 14, 693 (2020). [5] K. Kaiser et al. arXiv:2211.01051 (2022).