TUT 1: Tutorial: Plasmonics (HL with O)

Organizer: Harald Giessen (Universität Stuttgart)

The tutorial Plasmonics and Nanooptics covers highly topical subjects in the fields of nanooptics and plasmonics. The topics include novel methods of bottom-up fabrications of functional plasmonic nanostructures with DNA-origami (Na Liu, University of Heidelberg und MPI for Intelligent Systems, Stuttgart), complex functional plasmonics with hybrid systems (Harald Giessen, University of Stuttgart), application as novel sensors (Hatice Altug, EPFL Lausanne, Switzerland), as well as infrared plasmonics with novel 2D materials such as graphene and hexagonal boron nitride (Rainer Hillenbrand, Nanogune San Sebastian, Spain).

The tutorial is aiming at students and postdocs who would like to get an overview of the fields of plasmonics and nanooptics, as well as at researchers who are interested in the most exciting new developments directly from leading scientists in the field.

Time: Sunday 16:00–18:30 Location: H15

Tutorial TUT 1.1 Sun 16:00 H15

Graphene and Metal Plasmonics for Mid-IR Biosensing — •Hatice Altug — Bionanophotonics Systems Laboratory, EPFL Lausanne, Switzerland

Mid-IR absorption spectroscopy is a powerful label-free biosensing technique enabling chemical identification of molecules through their vibrational fingerprints. However, the method is not effective in detecting nanometric biomolecules due to the large size-mismatch with several microns long Mid-IR light. By engineering on-chip plasmonic nano-antennas, we overcome this fundamental limitation and enhance intrinsic signals of molecules by many orders of magnitude. Using extreme field concentration we also monitor in real-time and in-situ biomolecular interactions from low quantities of molecules. Most recently we showed that graphene could revolutionize biosensing due to its exceptional opto-electronic properties. Graphene plasmons can be tuned by electrostatic gating, in contrast to conventional plasmonic materials such as noble metals. By exploiting this unique feature we demonstrated a dynamically tunable plasmonic Mid-IR biosensor that can extract complete optical properties of proteins over a broad spectrum.In addition, the extreme light confinement in graphene*up to two orders of magnitude higher than in metals*produces an unprecedentedly strong overlap with nanometric biomolecules, enabling superior sensitivity. The combination of tunable spectral selectivity and enhanced sensitivity of graphene opens exciting prospects for sensing, not only proteins but also a wide range of chemicals and thin films.

Tutorial TUT 1.2 Sun 16:45 H15

Active 3D plasmonics — •Na Liu — Kirchhoff Institute for Physics, University of Heidelberg — MPI for Intelligent Systems, Stuttgart, Germany

Active control of three-dimensional configuration is one of the key steps towards smart plasmonic nanostructures with desired functionalities. We lay out a multi-disciplinary strategy to create active 3D plasmonic nanostructures, which execute DNA-regulated conformational changes on the nanoscale.

Construction of 3D reconfigurable plasmonic nanostructures witnesses major technological limitations, arising from the required subwavelength dimensions and controlled 3D motion. There have been considerable efforts on integration of plasmonic nanostructures with active platforms using top-down techniques. Here we lay out and implement a multi-disciplinary strategy to create active 3D plasmonic nanostructures by merging plasmonics and DNA nanotechnology on the nanoscale. First, we show the creation of a reconfigurable plasmonic switch, which can execute DNA-regulated conformational changes. In one role, DNA works as molecular platform for organizing plasmonic nanoparticles into a 3D architecture. In the other role, DNA is used as fuel to drive the constructed 3D plasmonic switch along fully programmable routes. Simultaneously, the 3D plasmonic switch serves as optical reporter, which transduces its own conformational information into optical circular dichroism changes upon external stimuli in real time. We also demonstrate the first plasmonic walker.

Coffee Break

Tutorial TUT 1.3 Sun 17:30 H15

Infrared nanoscopy and nano-FTIR spectroscopy by elastic light scattering from a scanning probe tip — •Rainer Hillenbrand — CIC nanoGUNE, San Sebastian, Spain

With the development of scattering-type scanning near-field optical microscopy (s-SNOM) [1] and nanoscale FTIR spectroscopy [2,3], the analytical power of IR and THz imaging has been brought to the nanometer scale. The spatial resolution of about 10 - 20 nm opens a new era for modern nano-analytical applications such as chemical identification, free-carrier profiling and near-field mapping of plasmons.

s-SNOM and nano-FTIR spectroscopy are based on elastic light scattering from AFM tips. Acting as an optical antenna, the tip convert the illuminating light into strongly concentrated near fields at the tip apex, providing a means for localized excitation of molecule vibrations, plasmons or phonons in the sample surface. Recording the tip-scattered light yields nanoscale-resolved IR images and spectra, beating the diffraction limit by orders of magnitude.

After a brief overview of fundamentals and applications, recent achievements such as IR-spectroscopic nanoimaging of polymers and proteins [4] will be presented, as well as the launching and mapping of ultra-confined plasmons in graphene [5,6].

[1] F. Keilmann, R. Hillenbrand, Phil. Trans. R. Soc. Lond. A 362, 787 (2004) [2] F. Huth, et al., Nature Mater. 10, 352 (2011) [3] F. Huth, et al., Nano Lett. 12, 3973 (2012) [4] I. Amenabar, et al., Nat. Commun. 4:2890 (2013) [5] J. Chen et al., Nature 487, 77 (2012) [6] P. Alonso Gonzalez et al., Science 344, 1369 (2014)

Tutorial TUT 1.4 Sun 18:00 H15

Complex functional plasmonics: Ultrafast hybrid nonlinear plasmonics — •Harald Giessen — 4th Physics Institute and Research Center SCoPE, University of Stuttgart

We are going to present several different concepts on ultrafast nonlinear hybrid plasmonics. Both second- and third-harmonic processes are studied. The first concept incorporates strong local nonlinearities such as nanocrystals of nonlinear materials like $LiNbO_3$ and ITO into gaps of plasmonic nanoantennas [1]. The second concept investigates the nonlinearities of the metals itself, particularly the influence of the localized density of states in the d-band and its influence on the nonlinear optical processes [2]. The third concept uses Miller's rule to enhance the optical nonlinearity by tailoring the linear response such that the first order susceptibility is resonant with the second harmonic light [3]. This leads to a strong and reproducible enhancement of the nonlinear response. Our general method is particularly well suited to incorporate also localized quantum emitters into the gap and investigate nonlinear optical processes on the single particle level.

[1] B. Metzger et al., Nano Lett. 14, 2867 (2014). [2] B. Metzger et al., Opt. Lett. 39, 5293 (2014). [3] B. Metzger et al., Nano Lett. 15, 3917 (2015).