Molecular Plasmonics 2015

7.-9. May 2015, IPHT Jena (Germany)

Summary

Plasmonic effects based on localized surface plasmon resonance (LSPR) represent an emerging field between nanooptics and life-sciences with a great potential for applications especially in diagnostics and therapy. This year – in a series of similar symposia aiming at recent developments in molecular plasmonics bi-annually since 2005 (cf. http://molecular-plasmonics.de/) - was focused on bioanalytical and nanophotonic applications of plasmonic effects at nanoscale metal structures, utilizing the phenomenon of localized surface plasmon resonance (LSPR). This includes e.g. phenomenon occurring at molecular components due to local field-enhancement effects, interactions in hybrid nanostructures as well as comparisons of simulations with experimental results.

Description of the scientific content and discussion

The meeting started with a keynote-lecture by Uwe Kreibig over historical and scientific aspects of Plasmonics. This excellent talk initiated an intensive discussion over the future tasks of this focus. The first session was aimed on novel approaches the plasmonic nanostructures. Novel hybrid nanostructures consisted from self-assembled DNA/Au NP nanotubes and chains, switchable DNA machines that reveal switchable ON-OFF fluorescence properties, and innovative sensor structures for DNA and explosives were presented by Professor I. Willner (The Hebrew University of Jerusalem, Israel). For novel biosensings a concept of electrically-driven plasmon resonances in nanostructures were introduced (Dathe/IPHT). This system based on metal-insulator- semiconductor (MIS) structures allows for the measurement of molecular bindings with a high sensitivity. For the field of high optical resolution (STED) the possibility to locally enhance the power of the depletion beam by coupling it with the plasmon resonance of metallic nanoparticles were presented, that achieve high depletion intensities with low laser powers by exploiting the near-field enhancement occurring near the nanoparticles (Cortes/ICL). This concept is an improvement of existing STED nanoscopes and assists in the development of low-power, ultra-fast, low-cost nanoscopes. Near-field resolution of optical antennas was the focus of Heil et al. (B Cube). Here the resolution was based on emission of quantum dots as they pass a subwavelength nanoscopic slit structures. This allows the direct observation of the interaction characteristics and intensity distribution with nanometer precision

The second session was focused on the interactions between plasmonic nanostructures. The inducing of attraction and repulsion forces allows the

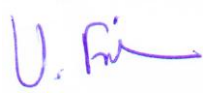
active switch in the optical system – individual nanoparticles can be directed to interact (Dienerovitz/UH Jena), resulting in high local field-enhancement of these structures. Fundamental aspects of single Au NP antennas and resulted heat transfer to the surroundings were presented by Hashimoto (University Tokushima). He showed simulations and real-measurements to 3D-heat transfer in this system. The Schmidt Group (cfae TU Dresden) showed novel waveguides consisting of nanoparticles and DNA-based self-assembly structures (6-helix bundle-type origami). This structures tries to realize optical short-range communication inside future computer chips or between microelectronic components. Additionally to particle-particle interactions, the interaction of particles and single molecules were addressed by Bald (University Potsdam). Here DNA origami based plasmonic nanostructures were realized for surface-enhanced Raman scattering (SERS) based detection of small molecules.
The afternoon session (Theory/Interactions) was started with an unconventional talk of Köhler (TU Ilmenau) with a novel interpretation of the optical behavior of plasmonic nanostructures. Here the contrast between a collective oscillation of electrons, which is a general effect of response of matter in case of elastic interactions and the resonant non-elastic interaction, which is assumed to be always a single-photon-single-electron process, was discussed on the example of microfluidic-prepared silver triangles. In a next talk, the hybrid nanostructures (spheres and rods) consisting of a photoactive organic core and surrounding inorganic nanoparticles for SERS were presented (Ishow/Université de Nantes). The last talk aimed at chiroptical effects from plasmonic nanostructures with optical Second Harmonic Generation (Valev/University Bath). He showed that - compared to plasmonic local field enhancements what can be used to increase the interaction of light - the superchiral light can increase additionally the interaction within chiroptical (chiral optical) effects. Following the afternoon session poster talks started. 24 posters were presented here.

The Saturday morning session was focused on the enhancement of Raman signals by plasmonic nanostructures, SERS. Here some different novel structures were presented for SERS: DNA-templated growth of metal nanoparticles and metallized self-assembled phospholipid nanodisks (Keller/ University Paderborn). A special kind of SERS, the surface-enhanced hyper-Raman scattering (SEHRS) were presented by Gühlke (Humboldt Universität Berlin). This two-photon analogue of Raman scattering allows for conclusions about both the plasmonic properties of the nanostructures and the interaction between molecules and the metal surface. After this, the role of the click-chemistry to functionalize of plasmonic nanostructures was demonstrated by real-time SERS detection (Lamy de la Chapelle/Univ. Paris). TERS presents a detection method with an extremely high lateral resolution. Here the plasmon-assisted of the dimerization of p-nitrothiophenol (pNTP) was observed by surface enhanced Raman scattering (SERS) and TERS, and both method were compared (Zhang/IPHT).
The last session of the symposium was focused on plasmonic coupling effects. Toppari (University of Jyväskylä, Finland) presents results for the strong coupling between SPPs and molecular excitations (ME) of

fluorescence dyes, which manifests itself through the formation of new hybrid modes exhibiting Rabi splittings. The resonant and off-resonant interaction between quantum dot (QD) excitons and surface plasmon (SP) dipole fields from metal nanostructures induces an enhancement of the light emission efficiency of QDs.The electromagnetic coupling of two nanoparticles with a controlled distances lead to hybridization of the plasmon modes also in a near-field, such as was resented by Schaffernak (University of Graz). Last talk addressed also coupling effects, especially between bow-tie nanostructures and QDs in the gap (Gasparic/University of Graz) demonstrating their high application potential.

Assessment of the results and impact of the event on the future direction of the field

Molecular Plasmonics, the field combining the effect of localized surface plasmon resonance with the molecular world, represents a hot issue which is expanding and combining with adjacent fields. As the symposium showed again, SERS and plasmonic interactions are two emerging fields in this area. Bioanalytical applications are considered as the most probable (and fastest) possibility to commercialize the studied effects. Therefore, robuste detection and highly defined but also cost-efficient fabrication techniques are required, and will be certainly the subject of growing research in this area.



Jena, 3. July 2015 Dr. Wolfgang Fritzsche