ulm university universität uulm

Fakultät für Naturwissenschaften, Fachbereich Physik

Announcement

Plasmonics and Metamaterials

Description

Plasmonics represents the whole field of surface plasmons including material properties, excitation methods and applications. Surface plasmons are quantized oscillations of electrons coupled with electromagnetic waves localized and/or propagating at metal-dielectric interfaces.

Although the subject remained at the edge of photonics and solid state physics, several discoveries of the unique properties of plasmonic materials triggered research into new directions: nanoplasmonics, quantum optics and metamaterials.

Surface plasmons can be localized at unmatched level comparing to the light wavelength. This makes them very attractive for quantum optical applications requiring fast decay by Purcell effect and strong coupling with light emitters. On the other hand the optical resonances of plasmonic particles and surfaces are very sensitive to changes of the polarization of light and refractive index of the surrounding medium allowing for sensing devices.

Metamaterials are a new class of materials where the optical/acoustic/thermal response is determined by the cooperative coupling among many small engineered units (meta-atoms). Except for few exceptions these materials are not available in nature and have to be fabricated by self-assembly, lithography, or other methods. The plasmonic meta-atoms are much smaller than the wavelength and the optical response depends of the optical properties of the individual elements and their coupling. Thus, they differ considerably from bulk materials. Among the plasmonics metamaterials two classes have been intensively investigated: the metasurfaces (2D) and the hyperbolic metamaterials (3D). Some of the unusual properties achieved promise a new generation of potential applications, including flat optical devices, deep sub-wavelength imaging, optical trapping.

In this course the fundamentals plasmonics are presented, including physical properties, materials, nanoparticles, and other nanostructures. Fabrication techniques, including lithography, self-assembly, deposition and chemical growth will are discussed and compared. As well an introduction with examples to several computational methods used in plasmonics and nanooptics will be given. Recent applications of plasmonics and metamaterials will be presented.

Students will also learn some of the experimental techniques available, including different kinds of microscopy and spectroscopy.

Learning Outcomes

The students will obtain a grade based on a lab work which may include sample preparation, experimental characterization and optical measurements, or simulations of the optical properties of plasmonic particles or metamaterials. Students have to prepare a report of the experiments and do an oral presentation.

Content

Fundamental properties of surface plasmons. Scattering, exticntion and cross-sections. Optical resonances in isolated and coupled nanoparticles. Optical excitation. Electron beam excitation. Mie theory. Computational methods: FDTD, FEM, BEM. Multipoles. Plasmonic antennas. Graphene plasmonics.

Fabrication techniques of noble metal nanostructures. Surface-enhanced Raman scattering. Enhanced fluorescence. Optical forces and thermal effects of plasmons. Quantum plasmonics. Metamaterials: metasurfaces and hyperbolic metamaterials. Applications.

Prerequisites

Knowledge of geometrical and wave optics, Maxwell's equations and electromagnetism is recommended. Fundamentals of algebra and vector calculus is required.

Literature

***Books:**

“Principles of Nano-Optics” 2nd Ed., L. Novotny and B. Hecht, Cambridge 2014.

“Nanoplasmonics”, V. Klimov, Pan Stanford Publishing 2014.

“Modern Introduction to Surface Plasmons”, D. Sarid and W. Challener, Cambridge 2010.

“Metamaterials: Physics and Engineering Explorations”, N. Engheta, R. W. Ziolkowski, Wiley-IEEE, 2006.

“Optical Metamaterials: Fundamentals and Applications”, W. Cai, V. Shalaed, Springer, 2010.

***Journal papers and lectures script.**

Additional Information

Lecturer

Dr. Manuel Rodrigues Gonçalves
Building East, N25 / 5212
Phone: 23022
e-mail: manuel.goncalves@uni-ulm.de