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Module	***Plasmonics and Metamaterials***
Code	
Instruction language	English
ECTS credits	4
Attendance time	2 hours per week
Duration	1 semester
Cycle	Each winter semester
Coordinator	Dean of Physics Studies
Instructors	Dr. Manuel Rodrigues Gonçalves
Allocation to study programmes	Physics M.Sc., elective module Advanced Materials M.Sc., elective module
Recommended prerequisites	Classical Electromagnetism; Solid state physics; Fundamentals of optics; Algebra and mathematical analysis; Complex calculus.
Learning objectives	*Plasmonics* is a physics research field of fast development, which has connections with solid state physics, photonics and quantum optics. Whereas electronics deals with electrons in matter, or beams, and photonics deals with light beams in matter or vacuum, plasmonics applies to all electromagnetic excitations at the boundary between a material with high free electron density and a dielectric. Booth electron beams and light can excite plasmons, but the spacial confinement of light provided by surface plasmons is the highest in matter. An introduction to the fundamentals of plasmonics in thin films, single nanoparticles and complex nanostructures will be given. Most of these properties can be described using Maxwell electrodynamics. However, plasmons are also bosons and share some of the properties of the quantum world. For instance, a single photon can excite a single plasmon. Modern applications of sensing, including surface enhanced spectroscopy, radiative decay engineering are based on matter structures supporting surface plasmons. A review of application will be given, including microscopy and spectroscopy of surface plasmons. In the last 15 years a new direction of nanomaterials was developed, based on the properties of matter supporting surface plasmons: *plasmonic metamaterials*. Unlike photonic crystals, where the unit cell is of the order of the wavelength, a plasmonic metamaterials is built based on arrays of plasmonic nanostructures much smaller than the wavelength. The unusual optical properties arising from these materials enhance and extend the optical effects beyond those predicted by classical optics of bulk materials. The fundamentals and some applications of plasmonic metamaterials will be presented. Students who successfully passed this module • understand the mathematical description of electromagnetic waves in nano-optics • know the physical basis of surface plasmons and the preparation of plasmonic nanostructures

	• have a knowledge of the main microscopy and spectroscopy techniques as SNOM, PEEM, EELS, cathodeluminescence • can simulate some of the optical properties of plasmonic nanostructues and metamaterials
Syllabus	• Concepts of near-fields and far-fields • Fundamentals of surface plasmons in 1D, 2D, and 3D nanostructures • Light scattering, absorption and extinction of isolated nanoparticles and their near-fields; Mie theory • Fabrication techniques of noble metal nanostructures • Optical characterization techniques: dark-field spectroscopy; SNOM, EELS, PEEM; cathodeluminescence; fluorescence lifetime spectroscopy • Simulation methods of plasmonic particles • Surfaces-enhanced Raman scattering; optical forces; thermal plasmonics; radiative decay engineering • Quantum plasmonics **Lab experiments:** • Fabrication and optical characterization of plasmonic nanostructures • Angle-resolved spectroscopy • Surface enhanced Raman scattering • Simulations methods in plasmonics
Literature	• *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 • Journal papers and lectures script
Teaching and learning methods	Lecture 2 h/week Laboratory course
Workload	30 hours lecture 90 hours self-study and laboratory part Total: 120 hours
Assessment	The module assessment consists of a written report with oral presentation of an experimental/simulation method subject.
Examination	
Grading procedure	The module grade is equal to the examination grade.
Basis for	