OSE6650 - Optical Properties of Nanostructured Materials – Spring 2016

Class times	Tuesdays & Thursdays 1.30pm-2.45pm + simulation sessions (see schedule)
Room	CREOL A214 / Simulation sessions in CREOL A210
Instructor	Dr. Pieter G. Kik, Office 270, CREOL Building Phone 407-823-4622, e-mail kik@creol.ucf.edu
Website	http://sharepoint.creol.ucf.edu/kik/OSE6650
Office hours	Tuesdays and Thursdays 3pm – 4pm
Prerequisites	OSE5111 *Optical Wave Propagation* OSE5312 *Fundamentals of Optical Science*
Catalog description	*Theory and applications of nanostructured optical materials: effective medium theory, nanostructured surfaces, plasmon waveguides, nanophotonic circuits, metallic near-field lenses, collective modes in nanoparticle arrays, metamaterials.*

Detailed description

This course covers several topics dealing with the optical properties of nanostructured materials, with an emphasis on the changes in dielectric behavior due to finite size effects. In the first part of the course we will discuss effective medium theory, including the Maxwell-Garnet description of the refractive index of inhomogeneous materials. We will cover applications of nanostructured dielectrics, including engineered anisotropy on surfaces, as well as anti-reflection coatings based on sub-micron surface structures. The second part of the course will deal with the optical properties of nanostructured metallo-dielectric materials. We will introduce the concept of surface plasmons on metal nanoparticles, and discuss spectral control of the plasmon resonance by tuning shape, size, and dielectric environment. This single particle description will be extended to arrays of interacting metal nanoparticles, leading to the development of propagating modes with sub-wavelength lateral confinement. We will derive the dispersion relation of these plasmon waveguides, and experiments probing the essential features of plasmon waveguides will be discussed. The concept of localized plasmons will be extended to the interaction of nanoscale corrugations on metal surfaces with propagating surface plasmons, including anomalous transmission through hole arrays in thin metal films, and sub-diffraction limit imaging in the near-field using surface plasmons. We will discuss the concept of metamaterials: composite materials that have been nanostructured to obtain a specific dielectric response. We will discuss how this can give rise to negative refraction, and we will discuss an experimental realization of this concept. In the Third part we will cover the basics of photonic crystals and photonic bandgap (PBG) materials. Effects related to the optical density of states will be discussed, and passive and active PBG waveguide structures will be covered.

Optional textbooks

- “Plasmonics”, S. A. Maier
- “Surface Plasmon Nanophotonics”, M.L. Brongersma and P.G. Kik, Eds.
- “Principles of Nano-Optics”, Novotny and Hecht
- “Surface plasmons on smooth and rough surfaces and on gratings,” H. Raether
- “Near-field optics and surface plasmon polaritons,” Edited by: Satoshi Kawata

Assessment

Homework	15%
Midterm	25%
Paper presentation	25%
Simulation project	35%

<u>Preliminary schedule</u> – please always check the most recent schedule on the course website

Date	Subjects covered
1-12	Introduction / overview
1-14	Effective index of nanostructured materials
1-19	Near-fields and Near-field Microscopy
1-21	Surface plasmons on spherical metal nanoparticles - introduction, Mie theory
1-26	Dependence of localized surface plasmon resonance on particle size and host index
1-28	Dependence of localized surface plasmon resonance on particle shape + core-shell NP
2-2	Inter-particle interactions, nanoparticle plasmon waveguides
2-4	Applications of SPs on metal nanoparticles: biodetection 1 - SERS
2-9	Applications of SPs on metal nanoparticles: biodetection 2 - wavelength shift, tracers
2-11	Surface plasmons on planar metal films - dispersion relations
2-16	Surface Plasmon excitation and detection 1: near-field / grating couplers / prism coupling
2-18	Surface Plasmon excitation and detection 2: practical examples
2-23	Surface plasmons - waveguides - Long range SPPs
2-25	Transmissive SP Optics - perfect lens
3-1	Metamaterials and negative refraction
3-3	**PRESENTATIONS**
3-8	Spring Break
3-10	Spring Break
3-15	Photonic bandgap materials - basic principles, line and point defect modes
3-17	Pre-midterm recap
3-22	**Midterm exam**
3-24	Midterm results discussion / Fundamentals of EM simulation
3-29	No lecture
3-31	Simulation session 1, Introduction + example simulation (Room A210, 1pm-5pm)
4-5	No lecture
4-7	Simulation session 2, own project (Room A210, 1pm-5pm)
4-12	No lecture
4-14	Simulation session 3, own project (Room A210, 1pm-5pm)
4-19	No lecture
4-21	Project presentations (Room A214 1.30pm) + Simulation session 4 (A210, 2.15pm-5pm)
4-26	No lecture
4-28	**Final report due**