Metamaterials and Nanophotonics (fall term 2020)

Lectures program

Lecturers: Prof. Tretyakov (TR) and Prof. Simovski (SIM)

Lecture 1 (TR, SIM) 07.09
Introduction to the course: course content, motivation - what changes if light "sees" particles, which are smaller or comparable in size with the wavelength and why this is important, a bit of history, current research focuses, future trends, application areas.

Lecture 2 (TR) 14.09
Electromagnetic waves in media: dispersion equation, phase and group velocities, waves in anisotropic and hyperbolic media, overview of applications.

Lecture 3 (TR) 21.09
Introduction into EM properties of materials: material parameters, causality and Kramers-Kronig relations, overview of properties of different materials in different frequency ranges, including optical properties of metals (Lorentz, Debye, Drude dispersion types).

Lecture 4 (TR) 28.09
Metamaterials: definition and why they are promising, meta-atoms, classification of possible response, engineered and extreme properties, superlenses, cloaks, tunable and software-defined material response.

Lecture 5 (TR) 05.10
Metasurfaces: averaged currents, single-layer arrays of resonant dipoles, including the notion of interaction constant, “extraordinary transmission” and “extraordinary reflection”, Huygens’ sheets, perfect absorption in metasurfaces, polarization transformers, etc.

Lecture 6 (SIM) 12.10
Introduction to photonic crystals: definitions of photonic crystals, living photonic crystals, Bragg’s phenomenon and its main implications, isofrequencies and dispersion diagram of lattices, Bloch’s theorem and quasi-periodicity, Brillouin zones, 2D and 3D photonic band structures, governing field equation of photonic crystals, their scalability and cell problem in numerical simulations of photonic crystals.

Lecture 7 (SIM) 26.10
Nanophotonic applications of photonic crystals: defect states for sensing and advanced LED, photonic crystals waveguides, optical drop-add filters, photonic crystals fibers, isofrequencies in boundary problems, isofrequencies for a hollow semiconducting photonic crystal, “all-angle” negative refraction and aberration-free parallel-plate focusing, superprism multiplexer/demultiplexer, list of important omitted topics.

Lecture 8 (TR) 02.11
Introduction to plasmonics: plasma and plasmons, plasmon resonance, plasmonic nanoparticles, plasmonic waveguides.

Lecture 9 (SIM) 09.11
Some nanostructures for optical sensing: Surface-Enhanced Raman Scattering (SERS) schemes for molecular sensors, Brillouin-Mandelstam and Smekal-Raman effects, electromagnetic model of SERS – surface field enhancement, fluorescence: spectroscopy and imaging of small objects, Plasmon-Enhanced Fluorescence (PEF) in optical biosensing, Purcell's effect, circuit theory of Purcell's effect, why SERS gain is giant, advanced SERS.

Lecture 10 (SIM) 16.11
Metatronics (platform for all-optical signal processing): optoelectronics in telecom and its inherent drawbacks, idea of all-optical signal processing, optical lumped circuits, metatronics based on ENZ and beyond ENZ, dielectric and metal-dielectric metasurfaces as miniaturized optical filters, asymmetric transmission of optical signals, graphene platform of metatronics.

Lecture 11 (SIM) 23.11
Nanostructures for enhancement of solar cells: what are solar cells (SCs), IV-plot of a SC and role of optical losses (OLs), anti-reflecting coatings (ARCs), integral and averaged OLs, satellite and terrestrial SCs, moth-eye ARCs for terrestrial SCs, black-silicon SCs, ARCs of nanospheres, thin-film solar cells and their OLs. Light-Trapping Structures (LTSs) for epitaxial Si solar cells, amorphous Si solar cells and organic SCs.

Lecture 12 (SIM) 30.11
Nanostructures for enhancement of TPV systems: what are thermophotovoltaic systems (TPVS), TPV cavity and TPV filter, Shockley-Queisser limit for SCs and its enhancement in TPVS, radiative heat transfer (RHT) and its optimization, TPVS as electric generators, solar TPVS, thermal emission and emissivity of a resonant metasurfaces, near-field TPVS, micro-TPVS, TPVS with few microns and submicron thick gaps, low-temperature TPVS.

Exam: Dec. 7

Retake exam Feb. 1