EC777: Nano-Optics

Instructor: Prof. Luca Dal Negro
Spring 2021 - Course Syllabus

Tue, Thu 3:30pm-5:15pm

1. Fundamental Concepts
   1.1. Review of EM fields and waves
   1.2. Multipolar expansion of electromagnetic fields
   1.3. Angular spectrum representation of optical fields
   1.4. Resolution limits in classical optics
   1.5. Classical dispersion model
   1.6. Semiclassical light-matter coupling: Fermi golden rule

2. Light Scattering, Plasmonics and Polaritonics
   2.1. Mie scattering theory
   2.2. Resonance of small nanoparticles
   2.3. Plasmonic cavities and nano-antennas
   2.4. Plasmonics and surface polariton waves
   2.5. Nanolasers and spasers
   2.6. Toroidal dipoles and anapole devices
   2.7. Numerical simulation approaches in nano-optics (coding examples)

3. Metamaterials and Complex Media
   3.1. What are metamaterials?
   3.2. Effective optical constants and homogenization
   3.3. Light in inhomogeneous media: multiple scattering
   3.4. Resonant multiple scattering of light
   3.5. Mesoscopic optics: weak localization
   3.6. Anderson light localization
   3.7. Random lasers

4. Extreme Light: Quantum Effects in Nano-Optics
   4.1. Quantization of oscillators
   4.2. Quantization of the EM field and transition rates
   4.3. Weak and strong coupling regimes
   4.4. Cavity polaritons and Bloch equations
   4.5. Quantum effects in plasmonics and nano-optics
   4.6. Quantum nano-optical devices
**Topics for students’ projects and presentations**

1. *Near-field microscopy techniques*
2. *Optical metamaterials*
3. *Topological photonics*
4. *Quantum plasmonics*
5. *Exciton-photon coupling and cavity polaritons*
6. *Light localization and random lasers*
7. *Plasmonics sensors*
8. *Anapole lasers*
9. *Jaynes-Cummings strong coupling*
10. *Dicke superradiance model*
11. *Photonic wires and dots*
12. *Low-dimensional semiconductors*

**Books:** notes will be distributed by the instructor per each topic.

**Textbook(s):**

*Principles of Nano-Optics (II Edition)* by L. Novotny and B. Hecht (Cambridge)

*Waves in Complex Media*, by L. Dal Negro (Cambridge University Press 2021)

**Additional references:**

*Quantum mechanics (2nd edition)* by N. Zettili (Wiley)

*Elements of quantum optics* by P. Meystre and M. Sargent III (Springer)

*Absorption and scattering of light by small particles* by C.F. Bohren, D.R. Huffman (John Wiley)

**Prerequisites for EC777 Nano-Optics:** Engineering optics (EC562) or equivalents, knowledge of optics and electromagnetic fields (E565) or equivalents, physics of semiconductor devices (EC471) or equivalents, introductory quantum mechanics (EC574) or equivalents. Under graduate students must discuss with the instructor before registering for this course.