EC777: Nano-Optics

Instructor: Prof. Luca Dal Negro Spring 2024 - Course Syllabus

1. Fundamental Concepts

- 1.1. Review of EM fields and waves
- 1.2. Green's functions
- 1.3. Multipolar expansion of electromagnetic fields
- 1.4. Classical theory of dispersion
- 1.5. Semiclassical light-matter coupling: Fermi golden rule
- 1.6. Quantization of electromagnetic field
- 1.7. Light-matter coupling models
- 1.8. Quantum correlation functions and photodetection theory

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. Classical theory of partial coherence
- 2.6. Computational methods 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. Two-level systems
- 4.2. Polaritons
- 4.3. Strong coupling regime
- 4.4. Cavity polaritons and Bloch equations
- 4.5. Master equation and photon correlations
- 4.6. Quantum effects in plasmonics and nano-optics
- 4.7. Elements of quantum theory of coherence

Topics for students' projects and presentations

- 1. Near-field microscopy techniques
- 2. Optical superresolution
- 3. *Optical metamaterials*
- 4. Topological photonics
- 5. Quantum plasmonics
- 6. Thermal effects in nano-optics
- 7. Light localization and random lasers
- 8. Anapole engineering and lasers
- 9. Jaynes-Cummings model
- 10. Correlation functions and photon noise

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

Additional references:

Principles of Nano-Optics by L. Novotny and B. Hecht (Cambridge University Press, 2012)

Nano and Quantum Optics by Ulrich Hohenester (Springer, 2020)

Waves in Complex Media by Luca Dal Negro (Cambridge University Press, 2022)

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

<u>Prerequisites:</u> 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.

Undergraduate students must discuss with the instructor before registering for this course.