Summary
Series of lectures covering the physics of quantum heterostructures, dielectric microcavities and photonic crystal cavities as well as the properties of the main light emitting devices that are light-emitting diodes (LEDs) and laser diodes (LDs).

Content
1. Semiconductor materials for optoelectronics
2. Semiconductor nanostructures, dielectric microcavities and photonic crystals
   Growth techniques, quantum wells, superlattices, quantum dots and single photon emitters, basic features of microcavities and photonic crystals, Purcell effect
4. Electroluminescence
   Light-emitting diodes, quasi-Fermi levels, emission spectra, efficiency, radiative and nonradiative lifetimes
   Applications: displays and solid-state lighting
5. Laser diodes
   Stimulated emission, material and modal gain, transparency and threshold currents, spectral characteristics, far-field and near-field emission patterns, efficiency, waveguides
   Fabry-Perot laser diodes, distributed feedback and vertical cavity surface emitting laser structures
   Bandgap engineering, quantum well laser diodes, separate confinement heterostructures
   Relaxation oscillation frequency
   Beyond conventional laser diodes: physics of high-β nanolasers
   Quantum cascade lasers

Learning Prerequisites
Recommended courses
Physics of semiconductors and fundamentals of light-matter interaction

Learning Outcomes
By the end of the course, the student must be able to:
• Sketch - and explain the band diagram of quantum engineered heterostructures (quantum wells, superlattices, quantum dots) subjected or not to an electric field
• Explain - the impact of the dimensionality of a semiconductor on excitonic properties
• Assess / Evaluate - the properties of single photon emitters and entangled photon sources made from semiconductor quantum dots
• Use - basic notions of quantum optics to classify light emitters: assessment of the coherence of a light-source via photon statistics (2nd-order correlation measurements)
• Explain - the origin of the enhancement of the spontaneous emission rate via the Purcell effect
• Assess / Evaluate - the performance of dielectric cavities (microcavities and photonic crystal slabs) in terms of quality factor and photon lifetime, Lambertian vs non-Lambertian light emission spectra
• Assess / Evaluate - the performance of LEDs: internal quantum efficiency, extraction efficiency, wall-plug efficiency, luminous efficiency, color rendering index of white light sources
• Link - the radiative and nonradiative carrier lifetimes to microscopic recombination paths in the framework of the ABC model (Shockley-Read-Hall, bimolecular recombination coefficient and Auger term)
• Explain - the operating behavior of light-emitting diodes and laser diodes by relying on rate equations
• Compute - the material gain of bulk semiconductors and quantum wells (notions of transparency and threshold currents, modal gain)
• Assess / Evaluate - the performance of laser diodes: output power, internal quantum efficiency, wall-plug efficiency
• Explain - the origin of the temporal coherence of laser diodes (narrow linewidth) and their modulation frequency (several Gbit/s for telecom applications)
• Distinguish - the main features of edge-emitting laser diodes and vertical cavity surface emitting lasers

Transversal skills
• Use a work methodology appropriate to the task.
• Plan and carry out activities in a way which makes optimal use of available time and other resources.
• Communicate effectively with professionals from other disciplines.
• Take feedback (critique) and respond in an appropriate manner.
• Summarize an article or a technical report.
• Access and evaluate appropriate sources of information.
• Demonstrate a capacity for creativity.
• Demonstrate the capacity for critical thinking

Teaching methods
Ex cathedra with exercises

Expected student activities
Read the bibliographical ressources in order to fully integrate and properly use the physical concepts seen in the lectures and the exercices
Be able to generalize the above-mentioned concepts to a wide variety of systems/devices

Assessment methods
Written exam (100%)

Supervision
Office hours Yes
Assistants Yes
Others Office hours: appointments to be arranged by email.

Resources
Bibliography
"Wave mechanics applied to semiconductor heterostructures", G. Bastard (Les éditions de physiques, Les Ulis, 1991)
"Optical processes in semiconductors", J. I. Pankove (Dover, New York, 1971)
Ressources en bibliothèque

- Optical processes in semiconductors / Pankove
- Diode lasers and photonic integrated circuits / Coldren
- Wave mechanics applied to semiconductor heterostructures / Bastard
- Optoelectronics / Rosencher