PHYS-434

Physics of photonic semiconductor devices

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Cursus	Sem.	Type
Electrical and Electronical Engineering	MA2, MA4	Opt.
Ing.-phys	MA2, MA4	Opt.
Microtechnics	MA2, MA4	Opt.
Minor in Quantum Science and Engineering	E	Opt.
Photonics minor	E	Opt.
Physicien	MA2, MA4	Opt.
Quantum Science and Engineering	MA2, MA4	Opt.

Language of teaching	English
Credits	4
Session	Summer
Semester	Spring
Exam	Written
Workload	120h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	2 weekly
Number of positions	

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. Semiconducting nanostructures

• Growth techniques

• Quantum wells, superlattices, quantum dots and single photon emitters

3. Dielectric microcavities and photonic crystals

• 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-Ã# nanolasers

• Quantum cascade lasers

Learning Prerequisites

Required courses

Semiconductor physics and light-matter interaction (PHYS-433)
Quantum physics I and II (Bachelor)
Solid State Physics I and II (Bachelor), Quantum Electrodynamics and Quantum Optics (Master)

Learning Outcomes

- 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 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

Weekly graded homeworks to secure 1 point out of 6 (16.6% of the final grade)
Read the bibliographical ressources in order to fully integrate and properly use the physical concepts seen in the lectures and the exercices

Assessment methods

Written exam (with 1 point out of 6 earned via compulsory weekly homeworks (16.6%))

Supervision

Office hours	Yes
Assistants	Yes
Forum	No
Others	Office hours: appoinments to be arranged by email.

Resources

Bibliography

Optoelectronics, Rosencher and Vinter, Cambridge University Press

Ressources en bibliothèque

- Optoelectronics / Rosencher

Notes/Handbook

"Optoelectronics", E. Rosencher & B. Vinter (Cambridge University Press, Cambridge, 2002)
"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)
"Diode lasers and photonic integrated circuits", L. A. Coldren & S. W. Corzine (John Wiley & Sons, Inc., New York, 1995)

Websites

- http://library.epfl.ch/en/beast?isbn=0486602753
- http://library.epfl.ch/en/beast?isbn=9780511754647
- http://library.epfl.ch/en/beast?isbn=2868830927
- http://library.epfl.ch/en/beast?isbn=9780470484128

Moodle Link

- https://go.epfl.ch/PHYS-434