PHYS-433

Semiconductor physics and light-matter interaction

Butté Raphaël

Cursus	Sem.	Type
Electrical and Electronical Engineering	MA1, MA3	Opt.
Ing.-phys	MA1, MA3	Opt.
Photonics minor	H	Opt.
Physicien	MA1, MA3	Opt.

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

Summary

Lectures on the fundamental aspects of semiconductor physics and the main properties of the p-n junction that is at the heart of devices like LEDs & laser diodes. The last part deals with light-matter interaction phenomena in bulk semiconductors such as absorption, spontaneous & stimulated emission.

Content

1. Electronic properties of semiconductors

- Crystalline structures and energy band diagrams
- Impurities and doping
- Carrier statistics in equilibrium and out-of-equilibrium
- Electron transport in weak and strong fields
- Generation and recombination processes

2. Theory of junctions and interfaces

- *p-n* and metal-semiconductor junctions
- Heterojunction interfaces

3. Light-matter interaction in semiconductors

- Fermi's golden rule, absorption, optical susceptibility, Bernard-Duraffourg condition (optical gain condition)
- Spontaneous and stimulated emission of radiation
- Dielectric function, optical constants
- Radiative lifetime, photoluminescence spectra

Learning Prerequisites

Recommended courses

Solid State Physics I and II (Bachelor), Quantum Electrodynamics and Quantum Optics (Master)

Learning Outcomes

By the end of the course, the student must be able to:

- Explain - the main electronic and optical properties of bulk semiconductors (band structure, doping, absorption, excitonic features) that are behind the first quantum revolution (transistors, LEDs and laser diodes)

- Identify - the main criteria governing the I-V characteristics of the p-n junction and explain its departure from ideality (role of defects and Joule heating)
- Classify - semiconductors depending on their doping level (non-degenerate vs degenerate semiconductors)
- Compute - the Shockley-Read-Hall term, the bimolecular recombination coefficient and the Auger term entering into the ABC model
- Compute - the absorption spectrum of direct bandgap bulk semiconductors
- Compute - the radiative lifetime of a 2-level system and that of a direct bandgap bulk semiconductor
- Explain - the main properties of tunnel diodes and solar cells

Transversal skills

- Give feedback (critique) in an appropriate fashion.
- Make an oral presentation.
- Demonstrate a capacity for creativity.
- Demonstrate the capacity for critical thinking
- Assess one's own level of skill acquisition, and plan their on-going learning goals.
- Summarize an article or a technical report.

Teaching methods

Ex cathedra with exercises

Expected student activities

Weekly graded homeworks for an extra point
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 (plus an extra point via weekly homeworks)

Supervision

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

Resources

Bibliography

S. M. Sze, "Physics of semiconductor devices" 2nd edition (or > 2nd ed.) (John Whiley & Sons, New York, 1981)
P. Y. Yu and M. Cardona, "Fundamentals of Semiconductors, Physics and Materials Properties" 2nd edition (or > 2nd ed.) (Springer, Berlin, 1999)
N. W. Ashcroft and N. D. Mermin, "Solid State Physics" (Saunders College Publishing, Fort Worth, 1976)
E. Rosencher and B. Vinter, "Optoelectronics" (Cambridge University Press, Cambridge, 2002)

Ressources en bibliothèque

- E. Rosencher and B. Vinter, "Optoelectronics"
- N. W. Ashcroft and N. D. Mermin, "Solid State Physics" (Saunders College Publishing, Fort Worth, 1976)
- S. M. Sze, "Physics of semiconductor devices" 2nd edition (or > 2nd ed.) (John Whiley & Sons, New York, 1981)
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