MICRO-523

Optical detectors

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Cursus	Sem.	Type
Electrical and Electronical Engineering	MA1, MA3	Opt.
MNIS	MA3	Obl.
Microtechnics	MA1, MA3	Obl.
Microtechnics	MA1, MA3	Opt.

Language of teaching	English
Credits	3
Session	Winter
Semester	Fall
Exam	Oral
Workload	90h
Weeks	14
Hours	**3 weekly**
Courses	3 weekly
Number of positions	

Summary

Students analyse the fundamental characteristics of optical detectors. Thermal and photoemissive devices as well as photodiodes and infrared sensors are studied. CCD and CMOS cameras are analysed in detail. Single photon detection is explained.

Content

• **Introduction**: Electromagnetic radiation, radiometric quantities, interaction of light with matter, classification of detectors, noise sources, detector figures of merit.

• **Opticla methods: few examples**: Synchrone detection and interferometers, position sensors, 3D imaging, Fourier optics and microscopy.

• **Thermal detectors:** Basic relationships, bolometers, thermocouples, pyroelectric detectors, applications.

• **Photoemissive detectors**: External photoeffect, vacuum photodiodes, photomultipliers, microchannels, applications

• **Photovoltaic detectors**: Photodiodes (p-n diodes, p-i-n diodes, schottky diodes), avalanche photodiodes, noise sources, ultimate limits of photovoltaic photodectection.

• **Ultra-fast photodiodes:** interface electronics, bandwidth, travelling wave photodiodes, Bit-Error-Rate, eye diagram, telecom applications.

• **CCD cameras:** Charge Coupled Devices (CCD): CCD principles and building blocks, CCD charge transport and image sensor architectures

• **CMOS cameras:** Photocharge detection, photodiodes in CMOS, traditional MOS photodiodes array sensor architectures, noise in photo detection systems, the APS (Active Pixel Sensor).

• **Infrared detectors:** Photoconductors, MCT cameras, QWIP.

• **Single photon detection**: PMT and photon counting, intensified CCD, electron bombarded CCD, electron multiplying CCD, SPAD and avalanche effect.

Keywords

Photodetectors, photodiodes, CCD cameras, CMOS cameras, single photon

Learning Prerequisites

Recommended courses

Bachelor in microengineering or in electrical and electronic engineering.
Courses: "physique III et IV", "composants semiconducteurs", "électronique I et II", "ingénierie optique I et II" et "capteurs".

Important concepts to start the course

Semiconductor physics, diodes and transistors, electronic amplifiers, optical lenses, micro-fabricated sensors.

Learning Outcomes

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

- Analyze the basics characteristics and the principles used in optical sensors.
- Develop the physical models for different photodetectors
- Formulate fundamental equations describing the behavior of optical detectors
- Optimize the photosensitive pixel.
- Design cameras adapted to different optical applications
- Interpret the datasheets of commercial optical sensors
- Solve rapidly and efficiently problems related to optical detectors

Transversal skills

- Summarize an article or a technical report.
- Communicate effectively with professionals from other disciplines.

Teaching methods

ex-cathedra courses and exercises.
Course will be teached in English but the slides and the script will content some french explanations

Expected student activities

- Regular attendance to lectures
- Resolution of exercises as home work prior to the session
- Resolution of "matter that matters" questions

Assessment methods

Oral exam during the exam session with 15 minutes preparation and 15 minutes discussion with teacher and oberver (100% of final grade)

Supervision

Office hours	No
Assistants	No
Forum	No
Others	Students can directly contact the teacher at any time

Resources

Bibliography

Electronic books accessible by VPN:

- Saleh, Teich, "Fundamentals of photonics", Wiley Interscience, Chapitre 17.

- Seitz, Theuwissen: "single photon imaging", Springer series in optical sciences, 2011.

- S. Sze, Kwok K. Ng, "Physics of semiconductor devices", Wiley Interscience, 2007.

Paper book:

- Theuwissen: "Solid-state imaging with charge-coupled-devices" Kluwer academic Publishers, 1995.

- Ohta: "CMOS image sensors and application", CRC Press, 2007.

Ressources en bibliothèque

- Physics of semiconductor devices / Sze
- Solid-state imaging with charge-coupled-devices / Theuwissen
- CMOS image sensors and application / Ohta
- Fundamentals of photonics / Saleh
- Single Photon imaging / Seitz

Notes/Handbook

Script in 3 volumes with french explanations and partially translated in English

Moodle Link

- http://moodle.epfl.ch/course/view.php?id=13501

Videos

- http://video.epfl.ch/2142/1/10