

## MICRO-523

**Optical detectors**

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Cursus	Sem.	Type
Electrical and Electronical Engineering	MA1, MA3	Opt.
MNIS	MA3	Opt.
Microtechnics	MA1, MA3	Opt.
Photonics minor	H	Opt.

Language of teaching	English
Credits	3
Session	Winter
Semester	Fall
Exam	Written
Workload	90h
Weeks	14
<b>Hours</b>	<b>3 weekly</b>
Courses	3 weekly
<b>Number of positions</b>	

**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.
- **Optical methods: few examples:** Synchronous 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 photodetection.
- **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 générale : électromagnétisme", "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 basic 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 taught in English but the slides and the script will contain 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

Written exam during the exam session (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](#)
- [Single Photon imaging / Seitz](#)
- [Fundamentals of photonics / Saleh](#)
- [CMOS image sensors and application / Ohta](#)

### 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>