MICRO-523

Optical detectors

Bruschini Claudio

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

Language of teaching	English
Credits	3
Session	Winter
Semester	Fall
Exam	Oral
Workload	90h
Weeks	14
Hours	**3 weekly**
Courses	2 weekly
Exercises	1 weekly
Number of positions	

Summary

Students analyse the fundamental characteristics of optical detectors, their architectures, selected applications and case studies. Photoemissive devices, photodiodes, infrared sensors and single-photon detectors are studied. CCD, CMOS and SPAD cameras are analysed in detail.

Content

- **Introduction**: Electromagnetic radiation, radiometric quantities, interaction of light with matter, classification of detectors, noise sources, detector figures of merit.
- **Optical methods: selected examples**: Synchronous detection and interferometers, position sensors, 3D imaging, Fourier optics and microscopy, superresolution microscopy techniques.
- **Photoemissive detectors**: External photoeffect, vacuum photodiodes, photomultipliers, microchannel plates, applications.
- **Photodiodes**: basic principles and structures, avalanche photodiodes, noise sources, ultimate photodectection limits, ultra-fast photodiodes.
- **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 photodetection systems, APS (Active Pixel Sensor), HDR (High Dynamic Range) imaging. Specialty cameras.
- **Infrared detectors:** InGaAs/InP heterojunctions, basic principles, metrology.
- **Single photon detection**: PMT and photon counting, intensified CCD, electron bombarded CCD, electron multiplying CCD.
- **Single-photon avalanche diodes (SPADs):** SPAD basic principles, metrology, silicon photomultipliers (SiPMs) vs SPAD arrays, imagers. Selected use cases (time-resolved imaging, LIDAR, Positron Emission Tomography, biophotonics).

Keywords

Photodetectors, photodiodes, CCD, CMOS and SPAD cameras, single-photon detection, metrology, applications.

Learning Prerequisites

Required courses

Bachelor in microengineering or in electrical and electronic engineering.

Recommended courses

"Physique générale : électromagnétisme", "Physique des composants semiconducteurs", "Electronique 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
- 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.
- Demonstrate the capacity for critical thinking

Teaching methods

Ex-cathedra courses and exercises
Course will be taught in English, the scripts will contain explanations in English and French

Expected student activities

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

Assessment methods

Oral exam during the exam session with time for preparation followed by discussion with teacher and observer (100% of final grade). Cheat sheet allowed, no other material.

Supervision

Office hours	Yes
Assistants	Yes
Forum	No

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.

Ressources en bibliothèque

- Physics of semiconductor devices / Sze, Ng
- Single photon imaging / Seitz, Theuwissen
- Fundamentals of photonics / Saleh, Teich

Moodle Link

- https://go.epfl.ch/MICRO-523