MICRO-523 **Optical detectors**

Bruschini Claudio

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

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

Summary

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

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, 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, array sensor architectures, noise in photodetection systems, APS (Active Pixel Sensor), HDR (High Dynamic Range) imaging. Specialty and advanced CMOS cameras (3D-stacking, BSI vs. FSI). On-chip optics and technology-related aspects.

• **Infrared detectors:** InGaAs/InP heterojunctions, basic principles, metrology.

• **Single-photon avalanche diodes (SPADs):** SPAD basic principles, metrology, silicon photomultipliers (SiPMs) vs. SPAD arrays, imagers. Selected use cases (time-resolved imaging, commercial systems & LIDAR, biophotonics & microscopy). Advanced SPAD cameras.

• **Single photon detection**: PMTs and photon counting, intensified cameras, hybrid detectors, electron-multiplying CCDs, low-noise CMOS imagers.

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", and "Capteurs".

Important concepts to start the course

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

Learning Outcomes

- 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.
- 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 and active participation
- Solve exercises and homework
- Discuss and answer key "Take-home Messages" questions

Assessment methods

Midterm quiz (~1/6 of final grade).
Oral exam during the exam session with time for preparation followed by interactive discussion with teacher (~5/6 of final grade). Cheat sheet allowed, no other material.

Supervision

Office hours	Yes
Assistant.e.s	Yes
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.

Ressources en bibliothèque

- Find the references at the Library

Moodle Link

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