Course guide
2301211 - IP - Integrated Photonics

Last modified: 29/05/2025

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 1004 - UB - (ENG)Universitat de Barcelona.

Degree: MASTER'S DEGREE IN SEMICONDUCTOR ENGINEERING AND MICROELECTRONIC DESIGN (Syllabus 2024). (Optional subject).

Academic year: 2025 **ECTS Credits:** 4.0 **Languages:** English

LECTURER

Coordinating lecturer: DANIEL NAVARRO URRIOS

Others: Segon quadrimestre:
CARLOS DOMÍNGUEZ HORNA - 11
JOAQUIN FANECA RUEDAS - 11
BLAS GARRIDO FERNÁNDEZ - 11
MAURICIO MORENO SERENO - 11
DANIEL NAVARRO URRIOS - 11
JAD SABEK - 11

LEARNING RESULTS

Knowledges:
KT01. Identify semiconductor devices, technological processes, the most appropriate microelectronic design tools, and relationships between these elements in order to integrate a given product or system into microelectronic technologies.
KT02. Describe the current state of scientific research and microelectronic industrial technology worldwide and their economic, social and environmental impact.
KT03. Describe the physical principles underlying current semiconductor devices in relation to their application, as well as their emerging trends, modelling and characterisation techniques.
KT04. Identify and describe the different manufacturing and characterisation processes in microelectronics and their applicability according to the functional and cost requirements of the final integrated product.
KT05. Describe the main methods and tools used to design integrated circuits and systems in accordance with the required functional specifications and cost of the final integrated product.

Skills:
ST01. Design integrated devices, circuits and systems for new products according to their applications, taking into account sustainability and energy efficiency requirements.
ST02. Apply the manufacturing techniques and processes and design, simulation and characterisation tools of semiconductor engineering and microelectronic design to provide a solution to a specific integrated system proposal.
ST04. Select appropriate sources of information from the scientific and technical literature, using appropriate channels, and integrate this information, demonstrating the ability to synthesise information, analyse alternatives and engage in critical debate.
ST06. Plan the different activities involved in successfully carrying out an assigned task within a team, managing time and resources appropriately.

Competences:
CT01. Design new devices and integrated systems that require the use of manufacturing techniques specific to microelectronic technologies or the use of microelectronic design tools.
CT02. Apply sustainability criteria to projects based on integrated microelectronic products.
CT03. Apply the processes of semiconductor engineering and microelectronic design to fields in diverse areas of science or engineering where integrated systems are required.
CT04. Generate questions and hypotheses, propose methodologies to address new research and innovation challenges, and demonstrate originality in approaching and solving problems requiring integrated solutions in microelectronic technologies.

TEACHING METHODOLOGY

master classes, theoretical-practical classes and a laboratory session

LEARNING OBJECTIVES OF THE SUBJECT

K1.1 Knowledge of the fundamentals of light propagation through one-dimensional and two-dimensional waveguides.
K1.2 Knowledge of the devices that are the basic components of integrated photonic systems, including waveguides, optical couplers, micro ring resonators or nonlinear photonic devices, among others.
K1.3. Knowledge of technological platforms for integrated photonic circuits, the basic technological steps for their manufacturing and hybrid optoelectronic integration techniques
K.1.4 Knowledge of various simulation tools for the design and modeling of photonic integrated systems

STUDY LOAD

Type	Hours	Percentage
Self study	70,0	70.00
Hours small group	12,0	12.00
Hours large group	18,0	18.00

Total learning time: 100 h

CONTENTS

Block 1. Overview of integrated photonic components and integration in a common platform, suitable materials and applications

Description:
This block will give an overview of integrated optical waveguides and working principles of various integrated photonics components (passive and active) mainly based on semiconductor materials.
• Introduction: Materials, functionalities, technology and applications (1 hour)
• Passive Components (6 hours)
Waveguides (1D and 2D)
Characterisation techniques
• Components (Routing, combiners, MUX, DEMUX,…)
• Active Components (5 hours)
Amplifiers and lasers
Modulators
Detectors

Related activities:
• Lab Activity at UB lab (2 hours). Measurement of insertion losses (coupling and propagation losses) using cut-back technique

Full-or-part-time: 14h
Theory classes: 12h
Laboratory classes: 2h

Block 2. In-situ LAB sessions, mostly with OptiFDTD software

Description:
Some of the devices studied in Block 1 will be designed and simulated using open softwares.
• Effective index analysis method to solve 2D waveguides (2 hours)
• 3 layers waveguide / slab waveguide. Modes calculation (2 hours)
• Introduction to OptiFDTD (1 hours)
• Optical Couplers (4 hours).
• Optical Coupler (1 hours)
• Mach-Zehnder (1 hours)
• AWG: Arrayed Waveguide Grating (1 hours)

Full-or-part-time: 8h
Laboratory classes: 8h

Block 3. Device Fabrication Technology

Description:
The design rules and technology for large-scale photonic integrated circuits will be reviewed.
• Integrated photonics technology overview (1 hours)
• Integrated photonic devices fabrication processes (4 hours)
Dielectric materials deposition techniques and multilayer stacks
Lithography (micro- and nanotechniques)
• Etching (Dry and Wet techniques) patterning and topographies
Metallization and other materials for passive dynamic components
Testing, assembly and qualificaton
• Integrated photonics market overview and opportunities (1 hour)

Related activities:
• Lab Activity at CNM (2 hours). Visit to the CNM Clean Room and Photonics Lab

Full-or-part-time: 8h
Theory classes: 6h
Laboratory classes: 2h

GRADING SYSTEM

Exercises (50%) and one exam (50%)

Temptative list of Exercises:
1. Simulations of a specific 2D waveguide using an open source software (effective index analysis method)
2. Report with analysis of experimental data taken in the UB lab.
3. Dispersion Curves and Evanescent field using OptiFDTD
4. Analysis of Optical Couplers using OptiFDTD.
To pass the course, the student must get a minimum score of 4/10 in each of the activities and an average overall score of 5/10

BIBLIOGRAPHY

Basic:
- Saleh, B.E.A. Fundamentals of photonics. 3rd ed. Hoboken: John Wiley & Sons, 2019. ISBN 9781119506874.
- Lifante, G. Integrated photonics: fundamentals [on line]. Chichester, West Sussex: John Wiley & Sons, 2003 [Consultation: 09/04/2024]. Available on: https://onlinelibrary-wiley-com.recursos.biblioteca.upc.edu/doi/book/10.1002/0470861401. ISBN 9780470861398.
- Reed, G.T.; Knights, A.P. Silicon photonics: an introduction [on line]. Chichester: John Wiley & Sons, 2004 [Consultation: 07/05/2024]. Available on: https://onlinelibrary-wiley-com.recursos.biblioteca.upc.edu/doi/book/10.1002/0470014180. ISBN 9780470014189.
- Iizuka, K. Elements of photonics. New York: John Wiley & Sons, Inc., 2002. ISBN 0471839388.