

Course guide

2301116 - SEMPHO - Semiconductor Photonics: Applications and Technology

Last modified: 15/05/2025

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 710 - EEL - Department of Electronic Engineering.
Degree: MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Optional subject).
Academic year: 2025 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: JOSE ANTONIO LAZARO VILLA
Others: Segon quadrimestre:
ALEXANDRA BERMEJO BROTO - 11
JOSE ANTONIO LAZARO VILLA - 11

PRIOR SKILLS

Basic background on engineering or science

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:

CE2. Demonstrate the understanding of the peculiarities of the quantum model for light-matter interaction.
CE3. Know the fundamentals of laser physics, the types of lasers and their main applications.
CE4. Demonstrate knowledge of the fundamentals of image formation, propagation of light through different media and Fourier Optics.
CE6. Have carried out a set of advanced laboratory works, similar to that of future experimental research work.
CE9. Ability to synthesize and present photonics research results according to the procedures and conventions of scientific presentations in English.

Generical:

CG1. Ability to project, design and implement products, processes, services and facilities in some areas of photonics, such as photonic engineering, nanophotonics, quantum optics, telecommunications and biophotonics.
CG2. Ability to modeling, calculate, simulate, develop and implement in research and technological centers and companies, particularly in research, development and innovation tasks in all areas related to Photonics.
CG4. Ability to understand the generalist and multidisciplinary nature of photonics, seeing its application, for example, to medicine, biology, energy, communications or industry

Transversal:

CT1. ENTREPRENEURSHIP AND INNOVATION. Knowing and understanding the mechanisms on which scientific research is based, as well as the mechanisms and instruments for transferring results between the different socioeconomic agents involved in R&D&I processes.
CT3. TEAMWORK. Be able to work as a member of an interdisciplinary team, either as another member, or performing management tasks in order to contribute to developing projects with pragmatism and a sense of responsibility, assuming commitments taking into account the available resources.
CT4. SOLVENT USE OF INFORMATION RESOURCES. Manage the acquisition, structuring, analysis and visualization of data and information in the field of the specialty and critically assess the results of this management.
CT5. ENGLISH. Accredite an adequate level of this language, both orally and in writing, in line with the needs that the graduates will have.

Basic:

CB6. Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context

CB7. Students should know how to apply the knowledge acquired and their problem-solving ability in new or little-known environments within broader (or multidisciplinary) contexts related to their area of study.

CB8. Students should be able to integrate knowledge and face the complexity of formulating judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgment.

CB10. Students should possess the learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.

TEACHING METHODOLOGY

Learning by:

- Hands-on practical design and laboratory technologies
- Lectures.
- Group work.
- Individual work.
- Laboratory Practices.
- Oral presentations.

LEARNING OBJECTIVES OF THE SUBJECT

Semiconductor photonics is an exciting field that combines semiconductor technology with the study of light. It focuses on the interaction between light and semiconductors, leading to various interesting applications as: High-speed data communication enabling transmission of data at high speeds over long distances using optical fibers; Compact and integrated devices leading to smaller, lighter, and more efficient devices for telecommunications, sensing, imaging, and biomedical diagnostics; Quantum technologies, where semiconductor photonics plays a role in emerging quantum technologies, including quantum communication and quantum computing; Energy efficiency, with lower power consumption in photonic circuits and energy-saving semiconductor-based light sources.

It will be covered by hands-on semiconductor photonics:

- Applications,
- Clean-Room and fabrication technologies,
- Design and laboratory measurement of semiconductor photonic devices, after theoretical introductory sessions.

STUDY LOAD

Type	Hours	Percentage
Hours small group	12,0	16.00
Self study	51,0	68.00
Hours large group	12,0	16.00

Total learning time: 75 h



CONTENTS

Introduction to the subject and technologies

Description:

- Subject introduction.
- Introduction to Semiconductor Photonics Technologies:
 - 1) Silicon Photonics greatest applications and limitations.
 - 2) Compound and hybrid photonics.
 - 3) Introduction to Semiconductor Photonics Design Tool to be used for design process along course: ANSYS Lumerical®.
(Special attention will be paid to integration of passive photonic devices based on Si and derivative materials)

Full-or-part-time: 12h 30m

Theory classes: 4h

Self study : 8h 30m

Applications introduction

Description:

- Examples of applications of Semiconductor Photonics to:
Communication, sensing, energy efficiency, robotics, quantum technologies, life sciences and health care and photonic quantum computer (QPU).
- Seminar(s) from top level research groups will present state-of-the-art applications and related research projects.

Full-or-part-time: 12h 30m

Theory classes: 4h

Self study : 8h 30m

Semiconductor Fabrication Techniques

Description:

- 1) Introduction to Semiconductor Physics.
- 2) Working principles and structure of active and passive semiconductor devices
- 3) Clean Room Fabrication Techniques:
 - Obtaining the semiconductor substrate
 - Deposition Techniques
 - c-Si thermal oxidation
 - Photolithography
 - Diffusions and implantations
 - From the wafer to the device

Related activities:

- Clean Room Fabrication Techniques.

Full-or-part-time: 18h 45m

Theory classes: 4h

Laboratory classes: 2h

Self study : 12h 45m



Design of Semiconductor Photonics Devices

Description:

- The objective is to do a complete design cycle, so that the main concepts, techniques and processes as used, at an introductory level. The objective will be the design of a ring resonator as a compact basic element providing precise wavelength selectivity, high Q-factor, compact size, tunability, low power consumption, versatility, ease of integration, and high sensitivity.
- The minimum required theoretical model will be provided to students not having previous knowledge of this kind of devices.
- 4 stages of design will be developed along the course: a) initial design for basic functionality; b) (basic) parameters optimization to meeting key performance parameters; c) analysis of random fabrication errors and their expected impact in the final design; d) layout design of the designed ring resonator in silicon photonics and derivative materials.
- Students will develop their own design, using academic licenses of the simulation and layout design software running in online calculation servers of the UPC.
- Design sessions will be complemented with seminar(s) from expert in fabrication of semiconductor photonic devices explaining key steps, as Process Design Kit (PDK)s from VLC Photonics (Hitachi Group) and - Centro Nacional de Microelectrónica (CSIC, Barcelona).

Related activities:

- Design with commercial software of a semiconductor photonics device.
- Automatic design process.

Full-or-part-time: 18h 45m

Laboratory classes: 6h

Self study : 12h 45m

Clean Room Fabrication and Characterization of Photonics Devices

Description:

- Manufacture of noncomplex photonic structures in the Clean Room.
- Characterisation of noncomplex photonic structures.
- Students will learn the basic techniques for characterizing semiconductor photonic devices (the specific device to be characterized will be decided at the beginning of the course, depending on the availability of possible previously designed devices).

Related activities:

- Fabrication of photonic structures with colloidal solutions in Clean Room.
- Laboratory measurement of semiconductor devices.
- Laboratory measurement of optical nanostructured devices.

Full-or-part-time: 12h 30m

Laboratory classes: 4h

Self study : 8h 30m

GRADING SYSTEM

The final grade of the subject will be obtained from the evaluation score of the design work that will be assessed at the end of the subject and the laboratory practices, according to the following criteria:

Laboratory practices: 50%

Design work: 50%

Attendance to the practical classes, both of design and laboratory, which account for 80% of the classes, is mandatory.



BIBLIOGRAPHY

Basic:

- Sze, S.M.; Lee, M.K. Semiconductor devices: physics and technology. 3rd ed.; int. stud. version. Singapore: Wiley, 2013. ISBN 9788126556755.
- Chrostowski, Lukas. Silicon photonics design. 1. Cambridge: Cambridge University Press,, 2015. ISBN 9781107085459.

Complementary:

- Nirmal, D.; Ajayan, J.; Fay, P.J. (eds.). Semiconductor devices and technologies for future ultra low power electronics [on line]. First edition. Boca Raton, Florida ; London ; New York: CRC Press, 2022 [Consultation: 07/07/2023]. Available on: <https://www.taylorfrancis.com/books/9781003200987>. ISBN 9781003200987.

RESOURCES

Other resources:

Tutorial material on basic topics about the contents of the subject will be offered to those students who may request or need it.