Universitat Autònoma de Barcelona

**2018/2019**

## Introduction to Photonics

Code: 100164
ECTS Credits: 5

| Degree | Type | Year | Semester |
| --- | --- | --- | --- |
| 2500097 Physics | OT | 3 | 0 |

## Contact

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## Use of languages

Principal working language: english (eng)

Some groups entirely in English: Yes

Some groups entirely in Catalan: No

Some groups entirely in Spanish: No

## Teachers

Jordi Mompart Penina

## Prerequisites

There are no prerequisites.

## Objectives and Contextualisation

The main objective of this subject is to study the technological applications of light emphasising the physical principles at the basis of the photonic systems. Specifically, we will study different light sources and detectors and the propagation of light in waveguides, photonic crystals, metamaterials and nonlinear media. We will also address how to modulate light by means of electro-optical and acousto-optical effects, spatial light modulators and filters.

## Skills

- Apply fundamental principles to the qualitative and quantitative study of various specific areas in physics
- Be familiar with the bases of certain advanced topics, including current developments on the parameters of physics that one could subsequently develop more fully
- Develop critical thinking and reasoning and know how to communicate effectively both in the first language(s) and others
- Develop independent learning strategies
- Develop the capacity for analysis and synthesis that allows the acquisition of knowledge and skills in different fields of physics, and apply to these fields the skills inherent within the degree of physics, contributing innovative and competitive proposals.
- Generate innovative and competitive proposals for research and professional activities.
- Respect the diversity and plurality of ideas, people and situations
- Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
- Use mathematics to describe the physical world, selecting appropriate tools, building appropriate models, interpreting and comparing results critically with experimentation and observation

## Learning outcomes

1. Based on the principles of optics, describe light propagation in optical fibres and waveguides, photonic crystals and nonlinear media.
2. Calculate the modes of optical waveguides or fibers and the coupling between waveguides.
3. Characterize the second- and third-order nonlinear response of an optical medium.
4. Describe the basic processes of light-matter interaction and the working principle of the laser.
5. Describe the different processes of light emission and detection.
6. Describe the longitudinal, transverse and frequency modulation of light.
7. Develop an understanding of the basics of the applications of light modulators in technological areas.
8. Develop an understanding of the general properties of metamaterials and their potential applications.
9. Develop critical thinking and reasoning and communicate ideas effectively, both in the mother tongue and in other languages.
10. Develop independent learning strategies.
11. Distinguish the industrial and scientific applications of lasers in areas such as medicine, biophotonics and metrology.
12. Generate innovative and competitive proposals for research and professional activities.
13. Identify current social, environmental and economic challenges in photonics.
14. Learn the basic principles of light propagation in periodic media.
15. Model laser emission using rate equations.
16. Respect diversity in ideas, people and situations.
17. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments

## Content

**1-Introduction**

1.1-What is Photonics?

1.2-Fundamental features of light according to Ray Optics, Wave and Electromagnetic Optics and Quantum Optics.

1.3-Applications and basic research.

**2-Light sources and detectors**

2.1-Thermal emitters: Incandescence, Blackbody radiation, the Sun, incandescent lamps and halogen lamps.

2.2-Non thermal emitters: Luminescence. Discharge lamps. Light emitting diodes.

2.3-L.A.S.E.R. Active medium. Basic processes of light-matter interaction. Pumping mechanisms. Threshold population inversion. Amplification coefficient. Optical resonators. Properties and applications of laser light. Types of lasers.

2.4-Detectors. General features. Linearity. Sensitivity. Response speed. Types of detectors.

**3-Light propagation**

3.1-Waveguides. Dielectric planar waveguides. Bidimensional waveguides. Optical fibers. Curved waveguides. Coupling between waveguides. Integrated optical systems.

3.2-Periodic structures. Photonic crystals. Dimensionality. Band structure. Defects. Metamaterials.

3.3-Nonlinear media. Second order nonlinearity: parametric oscillation and second harmonic generation. Third order nonlinearity: Optical Kerr effect and four wave mixing.

**4-Light modulation**

4.1-Longitudinal modulation. Electro-optical effects: Pockels effect, Kerr effect and liquid crystals. Acousto-optical effects. Magneto-optical effects: Faraday effect.

4.2-Transversal modulation. Spatial light modulators. Liquid crystal devices.

4.3-Modulation in frequency. Filters. Monocromators. Interferometers.

## Methodology

The directed activities consist in lectures (classes of theory) and classes of exercises.

In the lectures, the course contents will be discussed in detail always encouraging students participation by raising questions.

In the exercises classes, we will encourage the students to participate actively either asking questions or contributing to the resolution of the exercises during the class.

The required autonomous work of the student in this subject includes the study of theoretical concepts, the preparation and solution of exercises, the delivery of activities and the preparation of an oral presentation. This last activity will be done in group.

The materials for the theory and exercises classes will be posted in the UAB *Campus Virtual* of the subject.

## Activities

| Title | Hours | ECTS | Learning outcomes |
|---|---|---|---|
| **Type: Directed** | | | |
| Exercises classes | 13 | 0.52 | 2, 3, 10, 9, 12, 15, 17, 16 |
| Lectures (Theory classes) | 25 | 1 | 14, 7, 8, 5, 4, 6, 1, 10, 9, 11, 12, 13, 17, 16 |
| **Type: Autonomous** | | | |
| Preparation of activities to deliver | 7 | 0.28 | 10, 9, 12, 17, 16 |
| Preparation of the oral presentation | 7 | 0.28 | 10, 9, 11, 12, 13, 17, 16 |
| Study and preparation of the exercises | 29 | 1.16 | 2, 3, 10, 9, 12, 15, 17, 16 |
| Study of theory concepts | 38 | 1.52 | 14, 7, 8, 5, 4, 6, 1, 10, 9, 11, 12, 13, 17, 16 |

## Evaluation

The final mark of the subject will be obtained as follows:

- 35% : Mark of the first partial exam.
- 35% : Mark of the second partial exam.
- 15% : Mark of the activities to deliver.
- 15% : Mark of the oral presentation.

In order to apply these percentages, the mark in each of the partial exams should be equal or above 3,5 from 10. If the mark of one or both partial exams is below 3,5, the student has to do a retaking exam of the part of the subject failed with mark below 3,5. If a student has passed the subject but he/she would like to improve the mark of the written exams, he/she can do a retaking exam and the final mark of the subject will be calculated using the percentages shown above with the mark obtained in the retaking exam. If a student does not attend any of the exams or only attends one of the partial exams, his/her mark will be "No avaluable". In order to be able to attend the retaking exam, the student must have attended the two partial exams.

## Evaluation activities

| Title | Weighting | Hours | ECTS | Learning outcomes |
|---|---|---|---|---|
| Deliveries | 15% | 0 | 0 | 10, 9, 12, 17, 16 |
| First partial exam | 35% | 3 | 0.12 | 2, 5, 4, 9, 15, 17 |
| Oral presentation | 15% | 0 | 0 | 10, 9, 11, 12, 13, 17, 16 |
| Retaking exam first partial | 35% | 0 | 0 | 2, 3, 14, 7, 8, 5, 4, 6, 1, 9, 15, 17 |
| Retaking exam second partial | 35% | 0 | 0 | 2, 3, 14, 7, 8, 5, 4, 6, 1, 9, 15, 17 |
| Second partial exam | 35% | 3 | 0.12 | 2, 3, 14, 7, 8, 6, 1, 9, 17 |

## Bibliography


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-R. Mentzel, ***Photonics: linear and nonlinear interactions of laser light and matter.*** Springer (2007).

-C.L. Chen, ***Foundations for guided-wave optics***. John Wiley & Sons (2007).

-P.W. Milonni & J.H. Eberly, ***Lasers,*** John Wiley & Sons, Inc (1988).

-K. Shimoda, ***Introduction to Laser Physics***, Springer (1986).

-O. Svelto, ***Principles of Lasers***, 5$^{th}$ edition.Plenum Press (2010).

-J. D. Joannopoulos, S. G. Johnson, J. N. Winn, R. D. Meade, ***Photonic crystals. Molding the Flow of Light***. Princeton University Press (2008).

-N. M. Litchintser, I. R. Gabitov, A. I. Maimistov, V. M. Shalaev, ***Negative Refractive Index Metamaterials in Optics***, Progress in Optics **51**, Chapter 1, pp 1-68 (2008).

-R. W. Boyd, ***Nonlinear Optics***, Academic Press (2008).

**-**J. M. Cabrera, F. Agulló, F. J. López, ***Óptica Electromagnética: Materiales y aplicaciones***, Addison Wesley Iberoamericana, Iberoamericana, 2a Ed. (1998).