UAB
Universitat Autònoma de Barcelona

Introduction to Photonics

Code: 100164
ECTS Credits: 5

2025/2026

Degree	Type	Year
Physics	OT	3

Contact

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Teachers

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Teaching groups languages

You can view this information at the end of this document.

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 discuss some examples of light modulation.

Competences

- Act with ethical responsibility and respect for fundamental rights and duties, diversity and democratic values.
- 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
- Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, and before both specialist and general publics

- 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.
- Make changes to methods and processes in the area of knowledge in order to provide innovative responses to society's needs and demands.
- Take account of social, economic and environmental impacts when operating within one's own area of knowledge.
- 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
- Work independently, have personal initiative and self-organisational skills in achieving results, in planning and in executing a project

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. Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, in front of both specialist and general publics.
5. Describe the basic processes of light-matter interaction and the working principle of the laser.
6. Describe the different processes of light emission and detection.
7. Describe the longitudinal, transverse and frequency modulation of light.
8. Develop an understanding of the basics of the applications of light modulators in technological areas.
9. Develop an understanding of the general properties of metamaterials and their potential applications.
10. Distinguish the industrial and scientific applications of lasers in areas such as medicine, biophotonics and metrology.
11. Explain the explicit or implicit code of practice of one's own area of knowledge.
12. Identify current social, environmental and economic challenges in photonics.
13. Identify situations in which a change or improvement is needed.
14. Identify the social, economic and environmental implications of academic and professional activities within one's own area of knowledge.
15. Learn the basic principles of light propagation in periodic media.
16. Model laser emission using rate equations.
17. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
18. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.

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-Electro-optical effects: Pockels effect, Kerr effect, liquid crystals and spatial light modulators.

4.2-Acousto-optical effects.

4.3-Magneto-optical effects: Faraday effect.

Activities and Methodology

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Exercises classes	14	0.56	2, 3, 16, 17
Lectures (Theory classes)	27	1.08	15, 8, 9, 1, 6, 5, 7, 10, 12, 17
Type: Autonomous			
Preparation of activities to deliver	7	0.28	17
Preparation of the oral presentation	7	0.28	10, 12, 17
Study and preparation of the exercises	28	1.12	2, 3, 16, 17
Study of theory concepts	36	1.44	15, 8, 9, 1, 6, 5, 7, 10, 12, 17

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.

Annotation: Within the schedule set by the centre or degree programme, 15 minutes of one class will be reserved for students to evaluate their lecturers and their courses or modules through questionnaires.

Assessment

Continous Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Deliveries	15%	0	0	17
First partial exam	35%	3	0.12	2, 6, 5, 16, 17
Oral presentation	15%	0	0	4, 10, 11, 12, 14, 13, 17, 18
Retaking exam first partial	35%	0	0	2, 3, 15, 8, 9, 1, 6, 5, 7, 16, 17
Retaking exam second partial	35%	0	0	2, 3, 15, 8, 9, 1, 6, 5, 7, 16, 17
Second partial exam	35%	3	0.12	2, 3, 15, 8, 9, 1, 7, 17

Continuous assessment

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 and does not attend the retaking exam, his/her mark will be "No avaluable".

Single assessment

Students who have opted for the single assessment mode will have to take a final test consisting of an exam of the contents of the first partial. Afterwards, they will have to do an exam of the contents of the second partial. In both exams they will have to solve some exercises similar to those that have been worked on in the exercises sessions and also other more theoretical questions. These tests will take place on the same day, time and place as the second partial exam of the continuous assessment modality.

The student's mark will be the weighted average of the two previous activities, where each of the exams account for 42,5% of the mark, and of the mark of the oral presentation, which will have been made during the course on the day established for all students, and which represents 15% of the mark.

If the mark of the final exam does not reach 3.5 (out of 10) or if the final mark of the subject does not reach 5 (out of10), the student has another opportunity to pass the subject by means of a retaking exam that will be held on the same day, time and place as the retaking exam of the continuous assessment modality. In this exam, 85% of the grade, corresponding to the final tests, can be recovered. The oral presentation is not recoverable.

Use of AI

For this subject, the use of Artificial Intelligence (AI) technologies is allowed exclusively in support tasks, such as bibliographic or information search, text correction or translations. The student will have to clearly identify which parts have been generated with this technology, specify the tools used and include a critical reflection on how these have influenced the process and the final result of the activity. The non-transparency of the use of AI in this evaluable activity will be considered lack of academic honesty and may lead to a partial or total penalty in the grade of the activity, or greater penalties in cases of severity.

Bibliography

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

-O. Svelto, ***Principles of Lasers***, 5th 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).

Software

No specific software is required.

Groups and Languages

Please note that this information is provisional until 30 November 2025. You can check it through this link. To consult the language you will need to enter the CODE of the subject.

Name	Group	Language	Semester	Turn
(PAUL) Classroom practices	1	English	second semester	morning-mixed
(TE) Theory	1	English	second semester	morning-mixed