Photonics

Code: 106822
Credits: 6

2026/2027

Degree programme	Type	Course
Nanoscience and Nanotechnology	OP	4

Contact lecturer

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Group languages

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

Prerequisites

This course has no mandatory prerequisites. However, it is recommended that students have previously completed courses *106802 - Calculus* and *106798 - General Physics: Electricity and Magnetism*, as these provide the foundational knowledge necessary for a better understanding of the course contents.

Objectives

- Understand the fundamental concepts and principles of photonics and the interaction between light and matter.
- Understand the different models used to describe the propagation of light, from geometrical optics to quantum optics.
- Analyze the basic phenomena related to light propagation, polarization, interference, and diffraction.
- Understand the operating principles of the main light emitters and detectors, as well as their characteristic parameters.
- Understand the optical response of materials through classical models describing light-matter interaction.
- Apply photonics concepts to the characterization of materials and nanomaterials using optical and interferometric techniques.
- Introduce the fundamentals of quantum optics and the semiclassical description of light-matter interaction.
- Acquire basic experimental skills in polarization, interferometry, and diffraction techniques through laboratory sessions.

Learning outcomes

- CM21 (Acknowledge the contribution women have made to the study of nanoscale phenomena.) Acknowledge the contribution women have made to the study of nanoscale phenomena.
- KM36 (Recognise the physical principles underlying photonic and nanophotonic systems.) Recognise the physical principles underlying photonic and nanophotonic systems.
- SM29 (Propose suitable techniques to characterise the structure, microstructure and composition of nanomaterials and nano-systems.) Propose suitable techniques to characterise the structure, microstructure and composition of nanomaterials and nano-systems.

Contents

1. Introduction to Photonics and Nanophotonics.

2. Geometrical Optics. Snell's law, Abbe invariant, diopter equation, thin lens equation, microscopy (compound microscope and types of microscopes).

3. Wave Model and Propagation. Maxwell's equations, electromagnetic wave equation, harmonic wave, superposition principle, polarization, ellipsometry, polarimetry, characterization of advanced materials, superposition of waves with different frequencies, wave packet, group and phase velocity, temporal coherence.

4. Light Emitters and Detectors. Blackbody radiation, fluorescence, LEDs, laser light, photodetectors, and quantum efficiency.

5. Response of Material Media. Fresnel equations, dispersion, and the Lorentz model.

6. Interference and Diffraction. Coherent superposition, interference equation, Michelson interferometer, interferometric metrology, Fresnel diffraction, Fraunhofer diffraction, diffraction by multiple apertures, diffraction gratings, X-ray Bragg diffraction, and characterization of nanomaterials.

7. Quantum Optics. Semiclassical theory of light-matter interaction (quantum matter and classical light), coherent evolution, stimulated emission in two- and three-level systems, decoherence and spontaneous emission (phenomenological treatment), applications (qubit rotations, electromagnetically induced transparency, etc.), limitations of the semiclassical treatment, and introduction to the quantum description of light.

Laboratory Sessions.

Polarization, Michelson interferometer, Fraunhofer diffraction, and diffraction grating.

Learning activities and methodology

Title	Hours	ECTS	Learning outcomes
Self-study	32	1.28	CM21, KM36, SM29
Description of an optical phenomenon from an image	5	0.2	CM21, KM36, SM29
Preparation of an individual lab report	12	0.48	KM36, SM29
Problem-solving sessions	11	0.44	KM36, SM29
Tutorials	5	0.2	KM36
Lectures	32	1.28	KM36, SM29
Laboratory sessions	9	0.36	KM36, SM29

Problem solving	24	0.96	KM36, SM29

Lectures

The lectures will be devoted to the presentation of the fundamental concepts, principles, and models of the course. Active student participation will be encouraged through questions, conceptual discussions, and guided reflections aimed at fostering critical thinking and facilitating the progressive understanding of the subject matter. In addition, questions will be posed throughout the sessions to assess students' comprehension of the concepts covered and to promote continuous learning.

Problem-Solving Sessions

The problem-solving sessions will focus on the practical application of the concepts introduced in the lectures. Representative exercises from the different topics of the course will be worked through so that students develop the ability to identify the underlying physical phenomena, select appropriate solution methods, and perform quantitative analyses. Problem sets will be made available in advance through the virtual campus to encourage prior preparation and facilitate discussion and clarification of doubts during class.

Laboratory Sessions

The laboratory sessions will enable students to consolidate the knowledge acquired in the lectures through the direct observation and analysis of optical phenomena. Students will carry out experiments on light polarization, the Michelson interferometer, Fraunhofer diffraction, and diffraction-grating spectroscopy. During these sessions, they will become familiar with basic optical instrumentation, measurement techniques, experimental data analysis, and the physical interpretation of the results obtained.

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

Continuous assessment activities

Title	Weight	Hours	ECTS	Learning outcomes
First Partial Exam	30%	5	0.2	KM36, SM29
Second Partial Exam	30%	5	0.2	KM36, SM29
Laboratory report	15%	9	0.36	KM36, SM29
Optical phenomenon report based on a photograph	10%	0	0	CM21, KM36, SM29
Laboratory oral assessment	15%	1	0.04	KM36, SM29

The assessment of the course will be carried out through continuous evaluation according to the following weighting:

- First Midterm Exam: 30%
- Second Midterm Exam: 30%
- Laboratory Report: 15%

- Laboratory Oral Assessment: 15%
- Analysis of an Optical Phenomenon from a Photograph: 10%

Midterm Examinations

Two midterm examinations will be held throughout the semester. Each examination will assess the contents covered during the corresponding teaching period and will be announced sufficiently in advance. These examinations will evaluate the student's understanding of the theoretical concepts of the course, problem-solving skills, and their capacity for scientific analysis, synthesis, and reasoning. Each midterm examination will contribute 30% to the final grade of the course.

Laboratory Sessions

Laboratory sessions are mandatory and are designed to reinforce experimentally the concepts developed during the lectures and problem-solving sessions. Assessment of laboratory activities will be divided into two components:

- Laboratory Report (15%): Assessment will be based on the quality of the presentation of experimental results, their analysis and interpretation, and the student's ability to discuss findings and draw appropriate conclusions.
- Laboratory Oral Assessment (15%): This component will evaluate the student's understanding of the experimental procedures, the operation of the equipment used, and the physical interpretation of the obtained results.

Analysis of an Optical Phenomenon from a Photograph

This activity aims to promote the student's observational skills and their ability to identify and explain optical phenomena encountered in everyday life. Each student must submit an original photograph taken by themselves that illustrates an optical phenomenon related to the course contents. Along with the photograph, the student must submit a brief report describing the observed phenomenon and the physical principles that explain it. Assessment will take into account the relevance of the selected phenomenon, the scientific accuracy of the explanation, the quality of the analysis, and the clarity of the presentation. To be eligible for grade averaging and to pass the course through continuous assessment, students must obtain a minimum grade of 2.0 out of 10 in each of the two midterm examinations.

Resit Examination

Students who do not pass the course may take a resit examination on the date established by the degree coordinator. This examination will allow students to recover the assessment corresponding to the midterm examinations. The remaining assessment activities are not recoverable.

Use of Artificial Intelligence (AI)

In this course, Artificial Intelligence (AI) technologies may be used exclusively as learning support tools. Specifically, AI may be used for information and bibliography searches, improving the writing and style of texts prepared by the student, as well as for translation or language-review tasks. However, all answers, analyses, problem solutions, interpretations of results, and conclusions submitted in any assessed activity must be the result of the student's own work and personal reflection. AI may not replace the student's own intellectual contribution or generate directly the academic content submitted for assessment.

For activities involving the analysis of optical phenomena based on photographs, all submitted images must be original and taken by the student. Photographs generated, modified, or manipulated using artificial intelligence tools will not be accepted. Failure to comply with this requirement will result in a grade of zero for the corresponding activity.

Whenever AI is used in an authorized assessed activity, students must clearly indicate the extent of its use, specify the tools employed, and explain how they contributed to the development of the work. Lack of transparency regarding the use of AI will be considered a breach of academic integrity.

During in-person assessment activities, including midterm examinations, resit examinations, and any other individual assessment carried out in the classroom, the use of electronic devices, mobile phones, or artificial intelligence tools is strictly prohibited. Any use of such tools during an assessment activity will be considered an academic misconduct offence.

Academic Misconduct, Plagiarism, and Misuse of AI

Any irregularity committed during an assessment activity (academic fraud, plagiarism, or unauthorized use of AI, unless explicitly permitted in this course guide) that may lead to a significant alteration of the assessment outcome will result in a grade of zero for that activity. If the assessment activity is a mandatory requirement for passing the course, or if multiple irregularities occur in different assessment activities within the same course, the final course grade will be zero. In addition to the academic consequences described above, the University may initiate disciplinary procedures in accordance with its current regulations.

Bibliography

Theory textbooks

- J. Casas. Óptica. Universidad de Zaragoza
- E. Hecht. Optics. Addison-Wesley Publishing Company.
- M.V. Klein, T. E. Furtak. Optics. John Wiley & Sons
- Keigo Iizuka, Elements of Photonics Volume 1. John Wiley & Sons, Inc. ISBNs: 0-471-83938-8 (Hardback); 0-471-22107-4 (Electronic)
- R. Guenter. Modern Optics. John Wiley & Sons
- B.E.A. Saleh, M.C. Teich, Fundamentals of Photonics, second edition. John Wiley & Sons. ISBN: 978-0-471-35832-9
- F.G. Smith, J.H. Thomson, Optics, John Wiley & Sons Ltd. ISBN 0 471 91534 3
- Daniel A. Steck, *Quantum and Atom Optics* (2007); Oregon Center for Optics and Department of Physics. Oregon University http://atomoptics.uoregon.edu/~dsteck/teaching/quantum-optics/quantum-optics-notes.pdf
- P. Meystre and M. Sargent, *Elements of Quantum Optics*, Springer-Verlag, 4th edition, 2007.
- M. O. Scully and M.S. Zubairy, *Quantum Optics*, Cambridge U. P., 1997.
- D. F. Walls and G.J. Milburn, *Quantum Optics*, Springer-Verlag, 2nd edition, 2008.
- C. C. Gerry and P. Knight, *Introductory Quantum Optics*, Cambridge University Press, 2005.

Problems textbooks

- E. Hecht. Teoría y Problemas de Óptica. MacGraw-Hill
- M. López, J.L. Díaz, J.M. Jiménez. Problemas de Física volumen V. Óptica. Editorial Romo.
- M. Fogiel, THE OPTICS PROBLEM SOLVER, Research and Education Association. ISBN: 0-87891-526-5
- Lim Yung-kuo, Problems and Solutions on Opticsm. World Scientific. ISBN: 981-02-0438-8

Software

No specific software is required.

Course groups and languages

The information provided is provisional until November 30. After this date, you will be able to consult the language of each group through this link. To access the information, you will need to enter the course CODE

Type of teaching	Group	Language	Semester	Shift
(TE) Theory	1	Catalan	first semester	morning-mixed
(PAUL) Classroom practices	1	Catalan	first semester	morning-mixed
(PLAB) Practical laboratories	1	Catalan	first semester	afternoon