COURSE DATA

DATA SUBJECT

Code: 36542
Name: Photonic: Diffraction and Coherence
Cycle: Undergraduate Studies
ECTS Credits: 6
Academic year: 2025-26

STUDY (S)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Facultat de Física	4	Second quarter

SUBJECT-MATTER

Degree	Subject-matter	Character
1105 - Degree in Physics	Complements of Physics	ELECTIVES

COORDINATION

SAAVEDRA TORTOSA GENARO

SILVESTRE MORA ENRIQUE

SUMMARY

«Photonics: Difraction and Coherence» is an optional subject of the fourth year of the Degree in Physics, and has 6 credits assigned (45 classroom hours of theory-practice and 15 of laboratory). The course is an introduction to the study of the propagation of light in free space and imaging systems and is organized into two blocks:

In a first block notions of diffraction phenomena studied in previous years are reformularted using a plane-wave basis, which constitutes the so-called Fourier Optics. This new formulation allows to easily address the free propagation of light beams, the diffractional imaging, the holography and the information optical processing. With this formalization it can be seen, for example, how to reduce the diffractive effects in light beams used in modern kilometrer-large interferometers or enhance the power of spatial resolution of microscopes or telescopes.

In the topics included in the first block, it is assumed that light has a deterministic or *coherent* behavior, with a completely predictable temporal and spatial dependence. However, in many real situations, this may not be true. The randomness of the light can be due to its dispersion in scatering media, in turbulent fluids or simply because of the random nature of the spontaneous emission of light. The study of the fluctuations of light is known as Optical Coherence Theory and requires a statistical treatment of the elementary processes described in the first block of topics.

Therefore, the second block presents an introduction to these problems, focusing on the study of three simple characteristic situations: when field fluctuations at one point, but at different times, are not completely correlated —partial temporal coherence, when they are not in different points of the wavefront at the same moment — partial spatial coherence, and when the fluctuations affect independently the

different vector components of the electromagnetic field — partial polarization. The study of these situations allows us to understand, for example, the operation of the Michelson stellar interferometer for the measurement of diameters of astronomical objects, the white light imaging, or gain insight into the concepts of pure state and mixed state in physical systems and the appearance or not of interferencephenomena when they overlap.
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PREVIOUS KNOWLEDGE

RELATIONSHIP TO OTHER SUBJECTS OF THE SAME DEGREE

There are no specified enrollment restrictions with other subjects of the curriculum.

OTHER REQUIREMENTS

It is highly desirable that the students had previously studied the basic subjects of Mathematics and General Physics and the compulsory subjects Mechanics, Mathematical Methods, Electromagnetism and Optics.

COMPETENCES / LEARNING OUTCOMES

1105 - Degree in Physics

Ability to collect and interpret relevant data in order to make judgements.

Apply acquired knowledge to professional activities: know how to solve problems and develop and defend arguments in a clear and structured manner, drawing on that knowledge.

Basic & applied Research: acquire an understanding of the nature and ways of physics research and of how physics research is applicable to many fields other than physics, e.g. engineering; be able to design experimental and/or theoretical procedures for: (i) solving current problems in academic or industrial research; (ii) improving the existing results.

Clearly evaluate orders of magnitude and identify situations that are physically different but exhibit analogies, in order to apply known solutions to new problems. Problem-solving

Collaborate effectively in work teams, assuming responsibilities and leadership roles and contributing to collective improvement and development.

Communicate effectively, both orally and in writing, adapting to the characteristics of the situation and the audience.

Communication Skills (written and oral): Being able to communicate information, ideas, problems and solutions through argumentation and reasoning which are characteristic of the scientific activity, using basic concepts and tools of physics.

Conduct experiments independently, estimate uncertainties, and describe, analyse and critically evaluate experimental data based on the physical models involved. Experimental and laboratory skills.

Contribute to designing, developing and implementing solutions that address social demands, taking the Sustainable Development Goals as a reference.

Convey information, ideas, problems and solutions to both specialist and non-specialist audiences.

Demonstrate critical and self-critical thinking within the field of study, considering aspects such as professional ethics, moral values and the social implications of the different activities carried out.

Demonstrate knowledge and understanding of social inequalities based on sex and gender within this specific field of study; integrate the different needs and preferences based on sex and gender into the design of solutions and problem solving.

Demonstrate knowledge based on advanced textbooks and informed by current developments at the forefront of the field of study.

Demonstrate proficiency in English or another foreign language of interest through the use of scientific and technical literature, oral and written communication, coursework and international academic experiences.

Design experimental and theoretical procedures to solve common problems in academic or industrial research and to improve existing results.

Design laboratory experiments and independently analyse and critically evaluate the experimental data obtained.

Develop the tools, habits and learning techniques necessary to undertake further studies with a high degree of independence.

Foreign Language skills: Have improved command of English (or other foreign languages of interest) through: use of the basic literature, written and oral communication (scientific and technical English), participation in courses, study abroad via exchange programmes, and recognition of credits at foreign universities or research centres.

Gather and interpret relevant data to form judgements including reflection on relevant social, scientific or ethical issues relating to activities or projects.

Have a good understanding of the most important physical theories that explain the physical phenomena observed and described; their logical and mathematical structure and, where applicable, their experimental application or demonstration.

Have a good understanding of the nature of physics research, the ways in which it is carried out, and how physics research is applicable to many different fields such as engineering. Basic and applied research.

Integrate different areas of physics and relate them to other scientific disciplines from a broad perspective.

Interpret and perform calculations independently, using both small-scale and large-scale computing systems, including the development of software. Problem-solving and IT skills

Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.

Know programming languages and perform calculations and simulations on both a PC and a supercomputer.

Learn autonomously, making informed decisions in different contexts, issuing judgements based on

experimentation and analysis and transferring knowledge to new situations.

Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.

Literature Search: be able to search for and use physical and other technical literature, as well as any other sources of information relevant to research work and technical project development.

Model and solve problems: identify the essential elements of a process or situation and establish a working model of it. Make the necessary approximations to reduce a problem to a manageable level. Critical thinking to construct physical models.

Modelling & Problem solving skills: be able to identify the essentials of a process / situation and to set up a working model of the same; be able to perform the required approximations so as to reduce a problem to an approachable one. Critical thinking to construct physical models.

Physics general culture: Be familiar with the most important areas of physics and with those approaches which span many areas in physics, or connections of physics with other sciences.

Possesses a broad general knowledge of physics and its various fields.

Problem solving: be able to evaluate clearly the orders of magnitude in situations which are physically different, but show analogies, thus allowing the use of known solutions in new problems .

Propose creative and innovative solutions to complex situations or problems within the field of knowledge to respond to diverse professional and social needs.

Search and use physics and other technical literature, as well as any relevant information sources for research work and the technical development of projects.

Students must be able to apply their knowledge to their work or vocation in a professional manner and have acquired the competences required for the preparation and defence of arguments and for problem solving in their field of study.

Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.

Students must have acquired knowledge and understanding in a specific field of study, on the basis of general secondary education and at a level that includes mainly knowledge drawn from advanced textbooks, but also some cutting-edge knowledge in their field of study.

Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

Students must have the ability to gather and interpret relevant data (usually in their field of study) to make judgements that take relevant social, scientific or ethical issues into consideration.

Studies independently, enabling them to venture into new fields of physics and of science and technology in general.

To know how to apply the knowledge acquired to professional activity, to know how to solve problems and develop and defend arguments, relying on this knowledge.

Understand and master the use of the most commonly used mathematical and numerical methods.

Understand the most important experimental models in the field of physics. Be familiar with the use of basic instrumentation.

Understand the theoretical and practical fundamentals of physics, as well as the mathematical knowledge required for its formulation. General knowledge.

Use the basic concepts and tools of physics to present, both orally and in writing, information, ideas, problems and solutions through the argumentation and reasoning characteristic of scientific activity. Oral and written communication.

DESCRIPTION OF CONTENTS

Wave equation for the vector potential. Scalar transfer function and point spread function. Angular spectrum. Propagation of vector fields.

Paraxial transfer funtion and point spread function. Fraunhofer approximation versus Fresnel diffraction. Diffraction patterns of a diffracting screen. Vector paraxial beams. Effect of spherical illumination. Vector Gaussian beams. Holography.

Transmittance in amplitude of a thin lens. Action of lenses and mirrors on paraxial beams. Lenses as Fourier transformers. Optimal collimation and focusing of a laser beam. Optical information processing.

Introduction. The thin lens as a diffraction-limited imaging system. Generalization to diffraction-limited centered imaging systems. Particular cases: circular pupil and square pupil.

Random light and stationary fields. Light field coherence. Interferential fringes and degree of temporal coherence. Spectrally incoherent sources. Power spectrum. Diffraction with spectrally incoherent sources. Fourier transform spectroscopy.

1. Vector diffraction

Wave equation for the vector potential. Scalar transfer function and point spread function. Angular spectrum. Propagation of vector fields.

2. Diffraction of paraxial beams

Paraxial transfer funtion and point spread function. Fraunhofer approximation versus Fresnel diffraction. Diffraction patterns of a diffracting screen. Vector paraxial beams. Effect of spherical illumination. Vector Gaussian beams. Holography.

3. Action of lenses and mirrors in paraxial beams

Transmittance in amplitude of a thin lens. Action of lenses and mirrors on paraxial beams. Lenses as Fourier transformers. Optimal collimation and focusing of a laser beam. Optical information processing.

4. Diffrational theory of imaging

Introduction. The thin lens as a diffraction-limited imaging system. Generalization to diffraction-limited centered imaging systems. Particular cases: circular pupil and square pupil.

5. Spectrally incoherent light

Random light and stationary fields. Light field coherence. Interferential fringes and degree of temporal coherence. Spectrally incoherent sources. Power spectrum. Diffraction with spectrally incoherent sources. Fourier transform spectroscopy.

6. Spatially incoherent light

Quasi-monocromatic spatially incoherent sources. Propagation of a spatially incoherent field through a linear system. Van Cittert-Zernike theorem. Diffraction with spatially incoherent source: optical processing without lenses. Michelson's stellar interferometer. Imaging systems with spatially incoherent illumination.

7. Partially polarized light

Not polarized light and natural light: Polarization matrix. Stokes parameters, Poincaré sphere and degree of polarization. Coherent and incoherent superposition of polarization states. Action of polarizers and compensators. Interferences with partially polarized light. Depolarizing elements.

8. Laboratory Sessions

Session 1.- Young fringes with polarized light. Prism of Wollaston.
Session 2.- Young fringes with a quasi-monochromatic wide source.
Session 3.- Structure of the focal volume: Influence of the aperture stop.
Session 4.- Stability and structure of the transverse modes of a laser resonator.
Session 5.- Spectral analysis of a laser beam. Longitudinal modes of a laser cavity.

WORKLOAD

PRESENCIAL ACTIVITIES

Activity	Hours
Theory	45,00
Laboratory	15,00
Total hours	**60,00**

NON PRESENCIAL ACTIVITIES

Activity	Hours
Attendance at other activities	0,00
Individual or group project	0,00
Independent study and work	55,00
Preparation of lessons	15,00
Preparation for assessment activities	5,00
Resolution of case studies	15,00
Total hours	**90,00**

TEACHING METHODOLOGY

This course consists of several types of classes with different methodologies:

1. **Lectures and problem sessions at classroom** (24+12 = 36 hours). In these classes the conceptual and formal aspects of the subject are discussed. Practical examples will be solved, to suport theoretical concepts already presented. Problems will be proposed and solved.
2. **Interactive problem sessions with discussion** (9 hours). These classes will be devoted to clarify concerns raised during the study of theoretical concepts, reinforcing the theoretical and practical aspects of greatest difficulty, to check student progress in the matter and the resolution of the problems given to students.
3. **Practical sessions at laboratory** (15 hours). These classes are held in pairs in the laboratory experiments with the proposed script practice, which always have open questions for flexible implementation of the experimental work that suits to student initiatives. Quantitative experiments have to be contrasted with theoretical calculations predicted by the models developed in the theory.

EVALUATION

The assesment system is as follows:

1. **Written examinations** (50%). One part will assess the understanding of the theoretical-conceptual and formal nature of the subject, both through theoretical questions, conceptual questions and numerical or simple particular cases. Another part will assess the applicability of the formalism, by solving problems and critical capacity regarding the results. Proper argumentations and adequate justifications will be important in both cases.
2. **Continuous assessment** (25%). Assessment of exercices and problems presented by students, questions proposed and discussed in class, oral presentation of problems solved or any other

method that involves an interaction with students.

3. **Continuous assessment of lab sessions** (25%). In this part, the skills acquired in the laboratory sessions will be evaluated, as well as the preparation and documentation prior to the sessions, and a brief oral presentation of the work carried out by the student in one of the lab sessions. The delivery of memories of the practices carried out is not required.

These evaluation criteria are common to the first and second calls.

REFERENCES

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- J. W. Goodman, Introduction to Fourier Optics (Roberts & Co., 2005).
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- G. R. Fowles, Introduction to Modern Optics (Dover, 1989).
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