COURSE DATA

Data Subject	
Code	36542
Name	Photonic: Diffraction and Coherence
Cycle	Grade
ECTS Credits	6.0
Academic year	2021 - 2022

Study (s)

Degree	Center	Acad. year	Period
1105 - Degree in Physics	Faculty of Physics	4	Second term

Subject-matter

Degree	Subject-matter	Character
1105 - Degree in Physics	16 - Complements of Physics	Optional

Coordination

Name	Department
SAAVEDRA TORTOSA, GENARO	280 - Optics and Optometry and Vision Sciences
SILVESTRE MORA, ENRIQUE	280 - Optics and Optometry and Vision Sciences

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.

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.

OUTCOMES

1105 - Degree in Physics

- Knowledge and understanding of the fundamentals of physics in theoretical and experimental aspects, and the mathematical background needed for its formulation.
- 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.
- Ability to collect and interpret relevant data in order to make judgements.
- 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 .
- 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.
- 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.
- 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.
- 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.
- Learning ability: be able to enter new fields through independent study, in physics and science and technology in general.
- 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.
- 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 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 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.
- Students must be able to communicate information, ideas, problems and solutions to both expert and lay audiences.
- Students must have developed the learning skills needed to undertake further study with a high degree of autonomy.

LEARNING OUTCOMES

- Using the vector potential to explain the free propagation vector beams.
- Using the theory of angular spectrum of plane waves.
- Get the diffraction patterns of common diffracting screens.
- Handle fluently the concept of temporal coherence.
- Handle fluently the concept of spatial coherence.
- Learn the operation of imaging systems under spatially coherent and incoherent illumination.
- Describe non-defined polarization states of light.
- Mathematically represent partially polarized states of light.
- Analyze the interference of partially polarized light beams.
- Identify the action of polarizers and compensators on partially polarized light and their

interferences.

DESCRIPTION OF CONTENTS

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. Effect of spherical illumination. Vector Gaussian beams. Holography.

3. Action of lenses and mirrors in paraxial beams

Action of lenses and mirrors. Optimal collimation and focusing of a laser beam. Optical information processing.

4. Diffrational imaging

The lens as an imaging system. Diffraction-limited imaging systems. Introduction to the 3D imaging. Design of the point spread function: apodizing and super-solvent filters.

5. Spectrally incoherent light

Random light and stationary fields. Light field coherence. Spectrally incoherent sources. Power spectrum. Interferential fringes and degree of temporal coherence. Coherence time and spectral width. 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

ACTIVITY	Hours	% To be attended
Theory classes	45,00	100
Laboratory practices	15,00	100
Study and independent work	55,00	0
Preparation of evaluation activities	5,00	0
Preparation of practical classes and problem	15,00	0
Resolution of case studies	15,00	0
TOTAL	**150,00**	

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.

REFERENCES

Basic

- H. A. Haus, Waves and Fields in Optoelectronics (Prentice-Hall, 1984).
- J. W. Goodman, Introduction to Fourier Optics (Roberts & Co., 2005).
- J. D. Gaskill, Linear Systems, Fourier Transforms, and Optics (Wiley, 1978).
- E. Wolf, Introduction to the Theory of Coherence and Polarization of Light (Cambridge, 2007).
- J. N. Damask, Polarization Optics in Telecommunications (Springer, 2005).

Additional

- B. E. A. Saleh y M. C. Teich, Fundamental of Photonics (Wiley, 2007).
- G. R. Fowles, Introduction to Modern Optics (Dover, 1989).
- S. G. Lipson, H. Lipson y D. S. Tannhauser, Optical Physics (Cambridge, 1995).
- L. Mandel y E. Wolf, Optical Coherence and Quantum Optics (Cambridge, 1995).

ADDENDUM COVID-19

This addendum will only be activated if the health situation requires so and with the prior agreement of the Governing Council

TEACHING METHODOLOGY:

In case that health situation requires blended teaching, the teaching model approved by the Academic Degree Committee on July 23, 2020 will be adopted.

— Compulsory subjects: 50% student attendance in the classroom, while the rest of students attend the class in streaming broadcast. Two groups will be set with alternate days attendance to the classroom in order to guarantee 50% of teaching hours attendance for all students. Laboratory sessions will have a 100% attendance.

— Optional subjects: 100% attendance in all activities.

If a total reduction in attendance is necessary, classes will be broadcast by synchronous videoconference at their regular schedule, along the period determined by the Health Authority.