Universitat Autònoma de Barcelona

2023/2024

Applied Optics

Code: 100183
ECTS Credits: 6

Degree	Type	Year	Semester
2500097 Physics	OT	4	1

Contact

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Teaching groups languages

You can check it through this link. To consult the language you will need to enter the CODE of the subject. Please note that this information is provisional until 30 November 2023.

Teachers

Irene Estevez Caride

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Prerequisites

This subject does not have prerequisites but it is advisable that the student has taken the subjects of Optics and Optics Laboratory.
It is also advisable for the student to review the general concepts of electromagnetism and mathematics that he has learned in these subjects in the previous courses.

Objectives and Contextualisation

The general objective of the subject is to present to the student some fields of Optics, such as diffraction, image processing, holography and polarization that are fundamental within applied optics and that have not been deepened, or scarcely mentioned, in the subject of optics. In addition, the student works with the Fourier transform in two dimensions and will see the connections between optics and signal theory.
As more concrete objectives of the subject we can mention the learning of the formulation of the diffraction based on the application of the Fourier transform and its utility in the optical processing of the information.
The objective of numerical simulation practices and laboratory practices is to complement the learning of the concepts of the theoretical classes.
Regarding the contribution of this subject to the professional training of the student, the ability to reason critically and improve the ability to work as a team is highlighted. As for the experimental tools, it is one of the few elective subjects in which the student faces a job in the laboratory and the subsequent preparation of a report, which leads to an improvement in their capacity to elaborate data.

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
- Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals
- Communicate complex information in an effective, clear and concise manner, either orally, in writing or through ICTs, and before both specialist and general publics
- Formulate and address physical problems identifying the most relevant principles and using approximations, if necessary, to reach a solution that must be presented, specifying assumptions and approximations
- Make changes to methods and processes in the area of knowledge in order to provide innovative responses to society's needs and demands.
- Plan and perform, using appropriate methods, study, research or experimental measure and interpret and present the results.
- 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
- Using appropriate methods, plan and carry out a study or theoretical research and interpret and present the results
- Work independently, have personal initiative and self-organisational skills in achieving results, in planning and in executing a project
- Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.

Learning Outcomes

1. Analyse image formation for an optical system by using suitable approaches.
2. Analyse the result that the use of Fourier domain filters will produce in the final image.
3. Apply the theory of linear systems to image-forming optical systems.
4. Apply wave equation to describing the phenomena of diffraction.
5. 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.
6. Construct an optical image processing system.
7. Describe Fourier domain signal processing.
8. Describe a wave via the angular spectrum of plane waves and their application to wave propagation.
9. Describe molding wavefronts using diffractive elements based on holography.
10. Describe the characterization of linear and invariant systems using impulse response and transfer function.
11. Describe the principles of holography and their application to the generation of diffractive elements.
12. Explain the explicit or implicit code of practice of one's own area of knowledge.
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. Pose problems of the diffraction of beams of light for openings, using the necessary approaches, depending on size.
16. Programme an image-processing process in the Fourier domain.
17. Simulate wave propagation through a computer programme.
18. Use convolution to describe invariant linear systems.

19. Use critical reasoning, show analytical skills, correctly use technical language and develop logical arguments
20. Use the Fourier transform for spatial functions in two dimensions.
21. Work independently, take initiative itself, be able to organize to achieve results and to plan and execute a project.
22. Working in groups, assume shared responsibilities and interact professionally and constructively with others, showing absolute respect for their rights.
23. Carry out academic work independently using bibliography (especially in English), databases and through collaboration with other professionals

Content

I - Foundations.

1.- Fourier analysis in two dimensions. Linear and invariant systems.
2.- Scalar theory of diffraction. Kirchhoff's theorem.
3.- Diffraction through a rectangular opening. Diffraction through a circular opening. Diffraction through a network.

II - Image formation.

4.- Analysis of image forming systems.
5.- Incoherent lighting. Transfer function.
6.- Coherent lighting.

III - Optical processing of the image.

7.- Coherent optical processing.
8.- Spatial filtering: Complex filters. Recognition of images, improvement of the image.

IV - Holography.

9.- Foundations, registration, reconstruction.
10.- Relations between object and image.
11.- Volume holography. Holograms by reflection. Holography in color. Rainbow holography.
12.- Holographic Interferometry: by double exposure, in real time and with vibrant objects.
13.- Other applications.

LABORATORY PRACTICES:

1.- Fraunhofer diffraction.
2.- Filtering of spatial frequencies.
3.- Holography.
4.- Practices in MATLAB

Because of the special situation due to the pandemia, this course we will not be able to perform laboratory practices 1 (diffraction) and 2 (image processing). Instead, we will reinforce the numerical simulation of these phenomena developing two applets in matlab

Methodology

Theoretical lectures:

The teacher imparts the basic knowledge of the subject, making sure that the concepts are clear as well as the mathematical formulation of them. Although the student apparently does not have a very active participation in this type of teaching, it is necessary to promote their contribution to the maximum by favoring the expression of their ideas and doubts, both in the same class and outside the classroom.

The theoretical lectures are also the theoretical foundation that allows the student to perform the experimental practices.

Laboratory practices

Laboratory practices are very important because they allow applying theoretical knowledge to the real physical world and better understand the theoretical basis of the subject. On the other hand, students acquire skills in the performance of experimental work, use of laboratory equipment and processing of experimental results. In the case of this subject, students will learn to capture images with CCD cameras and analog-digital converters, store and process said data. They will also use various elements very common in optical laboratories, such as lenses, mirrors, light sources (laser, etc). They will also use the photo lab to reveal the holograms.
In summary, these practices will allow the student to acquire skills in experimental methodology and learn techniques that will be useful in their future professional life.

As mentioned in the contents, this course we will not be able to carry out laboratory practices 1 (diffraction) and 2 (optical processing). Instead, students will develop two simulation applets that implement the concepts developed in these practices.

Numerical simulations in matlab

In these practices, numerical simulations of the concepts developed in theory and of the phenomena visualized in the laboratory practices will be carried out. As a computer program, MATLAB will be used, due to its resemblance to the C language learned in another subject, and its easy use to visualize images.

Thus, these practices serve several purposes:

On the one hand the consolidation of the concepts learned in theory, to be able to program the studied equations changing the relevant parameters and visualize the results in the form of images

On the other hand, we learn to program in a versatile language and to implement methods of digital image processing. In this way you can see the analogies between optical processing and digital signal processing.

During the sessions in the computer rooms the students will be doing the exercises proposed by the teacher and that previously they have been given in some scripts. In this way they will acquire the knowledge to be able to perform the evaluation exercises.

This course we will reinforce this part. In addition to the sessions in the computer rooms, during the face-to-face classes we will implement the different contents of the course. We will learn how to make applets in Matlab and finally, students will develop two applets that simulate these laboratory practices: diffraction and image processing.

For the evaluation students will deliver the programs and a brief report presenting the results obtained in each of the proposed evaluation exercises.

Preparation of reports and laboratory questionnaires

The students receive some scripts that will guide them to perform the experimental practices. The practices are carried out in groups of 2 or 3 students supervised by a laboratory teacher. At the end of the practices they complete a questionnaire individually on some basic concepts that they have learned in their experimental work. On the other hand, they elaborate in group a very detailed report of one of the laboratory practices. Finally, for the evaluation of the report, this report is supplemented with a brief oral presentation and discussion of the most relevant results before the group of laboratory professors.

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.

Activities

Title	Hours	ECTS	Learning Outcomes
Type: Directed			
Laboratory practices	12	0.48	2, 1, 4, 3, 5, 6, 12, 14, 13, 19, 22, 18, 20
Numerical Simulation Practices	6	0.24	2, 1, 4, 3, 5, 12, 23, 14, 13, 16, 19, 17, 21, 22, 18, 20
Theoretical lectures	30	1.2	2, 1, 4, 3, 7, 11, 9, 10, 8, 12, 14, 13, 15, 19, 18, 20
Type: Autonomous			
Preparation of reports and laboratory questionnaires	22	0.88	2, 1, 3, 5, 6, 7, 11, 9, 10, 8, 12, 23, 14, 13, 15, 19, 17, 21, 22, 18, 20
Preparation of reports and programs of numerical simulation practices	16	0.64	2, 1, 4, 3, 5, 23, 14, 13, 16, 17, 21, 18, 20
Reading and theory study	39	1.56	2, 1, 4, 3, 7, 11, 9, 10, 8, 12, 14, 13, 15, 19, 21, 18, 20
Resolution of proposed problems	18	0.72	2, 1, 3, 12, 23, 14, 13, 15, 19, 21, 18, 20

Assessment

The evaluation of the subject will be carried out through the following weights:

Final exam (written test): 50%

Computer numerical simulations: 20%

o Program delivery
o Brief report presenting the results obtained in each of the proposed evaluation exercises

Laboratory practices:

o Questionnaires (holography): 3%
o Appletss: 7%
o Practice report: 12.5%
o Presentation and oral discussion of the report: 7.5%

Evaluation by written test:

The knowledge acquired by the student will be evaluated from the theoretical classes and the practices carried out in the laboratory. To this end, questions of a theoretical nature and questions related to laboratory practices will be formulated. The students will be able to take a brief form that they will deliver with the exam.
This written test can be retrieved. Recovery exam: in order to be eligible for the recovery exam, students must have been assessed at least 2/3 of the total score.

Evaluation of laboratory practices:
Attendance at laboratory practices is mandatory and must be done on the dates that will be announced at the beginning of the course. The delivery of the questionnaires and the internship report is also mandatory. The non-justif
ied absence (with medical report) to the practices will prevent the subject from being approved.

Evaluation of numerical simulations by computer:
Attendance to computer simulation sessions is mandatory and must be done on the dates that will be announced at the beginning of the course. It is also mandatory to deliver the programs and a brief report presenting the results obtained in each of the proposed evaluation exercises. The non-justified absence (with medical report) to these sessions will prevent the subject from being approved.

Single Assessment

Students who have accepted the single assessment(evaluation) modality will have to take a final test which will consist of a theory exam where they will have to answer a series of short questions. Then they will have to do a problem test where they will have to solve a series of exercises similar to those worked on in the problem sessions. When finished, they will deliver the individual laboratory report and various matlab codes. These tests will be held on the same day, time and place as the final exam tests.

The student's grade will be the weighted average of the four previous activities, where the theory exam will account for 25% of the grade, the problem exam 15% and the laboratory practice reports 30% and the of numerical simulation 30%.

If the grade of the final test does not reach a value of 4 or if the final grade of the subject does not reach a value of 5, the student has another opportunity to pass the subject by means of the remedial exam that will be held on the day of the remedial exam of the continuous assessment modality. In this test they can recover 40% of the grade corresponding to the theory and the problems. The practice part is not recoverable.

Assessment Activities

Title	Weighting	Hours	ECTS	Learning Outcomes
Computer numerical simulation practices	20%	0	0	2, 1, 4, 3, 5, 12, 23, 15, 16, 19, 17, 21, 18, 20
Final Exam Recovery	50%	3	0.12	2, 1, 4, 3, 5, 7, 11, 9, 10, 8, 15, 19, 21, 18, 20
Final exam (written test)	50%	3	0.12	2, 1, 4, 3, 5, 7, 11, 9, 10, 8, 15, 19, 21, 18, 20
Laboratory practices	30%	1	0.04	2, 1, 4, 3, 5, 6, 12, 23, 14, 13, 15, 16, 19, 17, 21, 22, 18, 20

Bibliography

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- M. Françon: Holografía. Paraninfo, 1977

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- Mº Luisa Calvo (Coordinadora): Óptica avanzada. Ariel, 2002 (Capítulo 4, Procesado óptico de la información, por J. Campos y M.J. Yzuel y Apéndice B, Propiedades de laTransformadade Fourier, por J. Campos y M.J. Yzuel).

General Optics Books:

- M.Born y E. Wolf: Principles of Optics, Seven (expanded) edition. Cambridge University Press (2005)

- J.Casas: Óptica. Librería Genera, Zaragoza (1995)

Software

Matlab will be used for computer simulations