VNIVERSITAT DE VALÈNCIA

Course Guide
43309 Photonic crystals and optical pulses

COURSE DATA

Data Subject	
Code	43309
Name	Photonic crystals and optical pulses
Cycle	Master's degree
ECTS Credits	6.0
Academic year	2023 - 2024

Study (s)

Degree	Center	Acad. year	Period
2150 - M.D. in Advanced Physics	Faculty of Physics	1	First term

Subject-matter

Degree	Subject-matter	Character
2150 - M.D. in Advanced Physics	7 - Optical waveguides and photonic crystals	Optional

Coordination

Name	Department
FERRANDO COGOLLOS, ALBERT	280 - Optics and Optometry and Vision Sciences
ZAPATA RODRIGUEZ, CARLOS	280 - Optics and Optometry and Vision Sciences

SUMMARY

Electromagnetism in periodic media. Propagation in photonic crystals and other micro-and nanostructured. Scattering properties and optical pulses. Ultrashort pulses. Forming optical pulses. Techniques for measuring ultrashort pulses. Applications.

PREVIOUS KNOWLEDGE

Relationship to other subjects of the same degree

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

Other requirements

OUTCOMES

2150 - M.D. in Advanced Physics

- Students should demonstrate self-directed learning skills for continued academic growth.
- Students should possess and understand foundational knowledge that enables original thinking and research in the field.
- Ser capaz de gestionar información de distintas fuentes bibliográficas especializadas utilizando principalmente bases de datos y publicaciones internacionales en lengua inglesa.
- Poseer la capacidad para el desarrollo de una aptitud crítica ante el aprendizaje que le lleve a plantearse nuevos problemas desde perspectivas no convencionales.
- Comprender de una forma sistemática el campo de estudio de la Física y el dominio de las habilidades y métodos de investigación relacionados con dicho campo.
- Analizar una situación compleja extrayendo cuales son las cantidades físicas relevantes y ser capaz de reducirla a un modelo parametrizado.
- Saber modelizar matemáticamente los problemas físicos sencillos nuevos, conectados con problemas conocidos. Ser capaz de expresar en términos matemáticos nuevas ideas.
- Comprender las técnicas de fabricación y caracterización de componentes de fibra óptica y sus aplicaciones.
- Comprender las bases teóricas de la propagación de la luz, tanto en el espacio libre, como en medios dieléctricos lineales y no lineales, así como en guías ópticas.
- Ser capaz de diseñar sistemas ópticos y dispositivos fotónicos para aplicaciones específicas de procesamiento de señales.
- Conocer los avances recientes en materiales, dispositivos y tecnologías emergentes de interés para la fotónica.

LEARNING OUTCOMES

At the end of the teaching-learning process the student will have learned:

1. Understanding the techniques of fabrication and characterization of fiber optic components and applications.
2. Understanding the theoretical basis of the propagation of light, both in free space, as in dielectric media and non-linear, as well as optical waveguides.
3. Being able to design optical systems and photonic devices for specific applications of signal processing.

4. Understanding the recent advances in materials, devices and emerging technologies relevant to photonics.

DESCRIPTION OF CONTENTS

1. Macroscopic Maxwell equations

Macroscopic equations and spatial averaging. Susceptibilities. Properties of the susceptibilities in dielectrics. Homogenization of composite structures. 3D wave equation in homogeneous media. 3D wave equation in inhomogeneous media. Metals. Energy of the electromagnetic field in a material medium: losses.

2. Electromagnetism in periodic media

Electromagnetism as an eigenvalue problem in frequency. Hermitian operators and orthogonality of modes. Symmetries and classification of electromagnetic modes. Periodic media. Floquet-Bloch theorem. Photonic band diagrams. Analysis of photonic crystals.

3. General theory of electromagnetic wave guiding systems

2D wave equation. Non-hermiticity and biorthogonality of modes. Symmetries and mode classification. Dispersion relation and waveguide properties.

4. Analysis and design of complex photonic devices

Modal expansion methods. Perturbation theory. Theory of coupled modes: application to complex waveguides. Resonances in photonic waveguides and cavities. Temporal coupled mode theory.

5. Basic properties and technology of ultrashort pulses

Motivation. Femtosecond pulses: properties. Basic diagram of a femtosecond laser. First applications: molecular dynamics, quantum control, high intensity physics, non-linear optics, material processing and micro-machining, biophotonics, new techniques of three-dimensional imaging formation, etc.

6. Description of ultrashort laser pulses

Time vs.frequency analysis. Time description of light signals. Spectral description. Physical insight of the analytical signal. Pulse time duration and spectral width. Numerical exercise. Time-frequency product: quality factor. Other useful relationships. Amplitude and phase contributions to the spectral width. Examples.

7. Dispersive effects. Space-time analogy

Propagation of pulses in dispersive quadratic media. Space-time analogy. Temporal lenses. Time-domain telescopes and microscopes. Frequency-to-time transformers. Pulse shapers. Spectral imaging systems. Time-to-frequency transformers. Temporal Talbot effect. Propagation of linearly-chirped pulses in quadratic media. Other applications.

8. Diffraction with pulsed light. Spatio-temporal effects

Near-field diffraction: general case. Formula for the integrated intensity. Diffraction with pulsed light vs diffraction with temporally non-coherent light. Propagation of a pulsed Gaussian beam. Application to the Fraunhofer region. Numerical application. Achromatic femtosecond optics.

WORKLOAD

ACTIVITY	Hours	% To be attended
Theory classes	39,00	100
Other activities	4,00	100
Seminars	3,00	100
Development of group work	8,00	0
Development of individual work	8,00	0
Preparing lectures	44,00	0
Preparation of practical classes and problem	44,00	0
TOTAL	**150,00**	

TEACHING METHODOLOGY

MD1 - Standar theory lecture
MD3 - Problems solving
MD4 - Problems
MD5 - Seminars.
MD6 - Visit to external scientific facilities and companies
MD7 - Addressed debate or discussion.

EVALUATION

The academic evaluation of this subject will be made by:

a) Assessment Exercises: Students solve theoretical questions and problems proposed to be delivered and / or defend during the evaluation sessions which will be scheduled by the teachers of the subject using, to publicize the calls, emails to the students identified in the "Aula Virtual" platform.

b) Evaluation of an individual oral presentation: Here the student will defend a topic related to the contents of the course to the teachers of the subject. The allocation of items will be announce early enough to ensure the adequate preparation of the prresentation.

The percentage allocated to each of these activities, over the total score will be:

* Evaluation exercises: 30%.

* Evaluation of oral presentation: 70%.

The student will also have the option of a single written exam, on the date stated in the exam schedule, if you have not made any of the above activities. This test can also be used to improve the final marks by the students who have been evaluated by the scheduled activities.

REFERENCES

Basic

- Joannopoulos, J. D., Meade, R. D. and Winn, J. N., Photonic Crystals: Molding the Flow of Light. Princeton.
- Snyder, A. W. and Love, J. D., Optical Waveguide Theory. Chapman and Hall.
- Haus, H. A., Electromagnetic Noise and Quantum Optical Measurements. Springer-Verlag.
- Cohen, L. (1995). Time-Frequency Analysis. Prentice Hall.
- Trebino, R. (2000). Frequency-Resolved Optical Gating: The Measurement of Ultrashort Laser Pulses. Kluwer Academic.
- Diels, J. C. and Rudolph, W. (2006). Ultrashort Laser and Pulse Phenomena. Academic Press.
- Weiner, A. M. (2009). Ultrafast Optics. Wiley.
- Torres-Company, V., Lancis, J. and Andrés, P. (2011), in Progress in Optics, Vol. 56 (editor Wolf, E). Elsevier.
- Orfanidis, S. J. (2002). Electromagnetic waves and antennas. Rutgers University.