Course guides
230563 - NLO - Non-Linear Optics

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Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Optional subject).
ERASMUS MUNDUS MASTER'S DEGREE IN PHOTONICS ENGINEERING, NANOPHOTONICS AND BIOPHOTONICS (Syllabus 2010). (Optional subject).

Academic year: 2020 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: Cojocaru, Crina Maria (coordinadora)

Others: Trull Silvestre, Jose Francisco

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE2. (ENG) Màster en Fotònica:
Demostrar que comprende las peculiaridades que comporta el modelo cuántico para la interacción luz-materia.
CE9. (ENG) Màster en Fotònica:
Capacidad para sintetizar y exponer los resultados de investigación en fótonica según los procedimientos y convenciones de las presentaciones científicas en inglés.
CE4. (ENG) Màster en Fotònica:
Demostrar que conoce los fundamentos de la formación de imagen, de la propagación de la luz a través de los diferentes medios y de la Óptica de Fourier.

Generical:
CG1. (ENG) Màster en Fotònica:
Capacidad para proyectar, diseñar e implantar productos, procesos, servicios e instalaciones en algunos ámbitos de la fotónica como los relacionados con la ingeniería fotónica, la nanofotónica, la óptica cuántica, las telecomunicaciones y la biofotónica

Transversal:
1. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

2. ENTREPRENEURSHIP AND INNOVATION: Being aware of and understanding how companies are organised and the principles that govern their activity, and being able to understand employment regulations and the relationships between planning, industrial and commercial strategies, quality and profit.

3. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

4. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

Basic:
CB6. (ENG) Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación
CB7. (ENG) Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio.
CB10. (ENG) Que los estudiantes posean las habilidades de aprendizaje que les permitan continuar estudiando de un modo que habrá de ser en gran medida autodirigido o autónomo.
CB8. (ENG) Que los estudiantes sean capaces de integrar conocimientos y enfrentarse a la complejidad de formular juicios a partir de una información que, siendo incompleta o limitada, incluya reflexiones sobre las responsabilidades sociales y éticas vinculadas a la aplicación de sus conocimientos y juicio.

TEACHING METHODOLOGY

- Lectures
- Problems
- Applications

LEARNING OBJECTIVES OF THE SUBJECT

This course will render an overview on the basic principles of second and third order nonlinear effects in optics and their most important applications, providing a sound background in this field. Starting from the basic equations governing different nonlinear processes, detailed solutions and approximations will be discussed. We will then extend to more complex systems, interactions and applications of nonlinear effects. The last part of the course aims to provide an overview in recent advances and state of the art of the field.

STUDY LOAD

Type	Hours	Percentage
Hours large group	24,0	32.00
Self study	51,0	68.00

Total learning time: 75 h

CONTENTS

1. Maxwell equations and polarization

Description:
1.1 Maxwell equations
1.2 Polarization and susceptibility: Lorentz model for bounded charges, index of refraction, hydrodynamic model for free electrons.

Full-or-part-time: 1h
Theory classes: 1h

2. Optics of Crystals

Description:
2.1 Maxwell equations and material relations in birrefringent crystals
2.2 Normal modes of propagation in crystals
2.3 Propagation of ordinary and extraordinary waves in crystals

Full-or-part-time: 1h
Theory classes: 1h

3. Nonlinear polarization

Description:
3.1 Nonlinear polarization
3.2 Classical derivation of nonlinear susceptibility: second and third order interactions
3.3 Nonlinear susceptibility symmetries
3.4 Effective nonlinear coefficient

Full-or-part-time: 1h
Theory classes: 1h

4. Nonlinear wave equations

Description:
4.1 Wave equations for nonlinear optics
4.2 Coupled mode theory for plane waves: quasi-monochromatic plane wave approximation, separation on frequencies approximation, slowly-varying amplitude approximation
4.3 Energy and phase relations in nonlinear optics

Full-or-part-time: 1h
Theory classes: 1h

5. Second order nonlinear effects (plane wave approximation)

Description:
5.1 General description of the second order processes
5.2 Coupled-wave equations for sum-frequency generation: coupled-amplitude equations, solution for non-depleted input waves, phase-matching considerations, Manly-Rowe relations, the case of one depleted input beam.
5.3. Second harmonic generation: phase matching techniques, different materials for SHG, applications
5.4 Difference-frequency generation and parametric amplification (OPA);
5.5 Optical parametric oscillations (OPO)

Full-or-part-time: 8h
Theory classes: 8h

6 Third order nonlinear effects (plane wave approximation)

Description:
6.1 Third harmonic generation and optical Kerr effect
6.2 Self and cross-phase modulation
6.3 Four-wave mixing: coupled wave theory for three wave mixing and third harmonic generation
6.4 Optical phase conjugation

Full-or-part-time: 4h
Theory classes: 4h

7. Nonlinear optics with beams and pulses

Description:
7.1 Basic equations for beams and pulses
7.2 Nonlinear interactions in Kerr media: self-phase modulation, self-focusing, filamentation and optical solitons
7.3 Parametric processes in quadratic media
7.4 Short pulse characterization

Full-or-part-time: 3h
Theory classes: 3h

8. Nonlinear light scattering and absorption

Description:
8.1 Light scattering
8.2 Brillouin scattering
8.3 Raman scattering
8.4 Two-photon absorption

Full-or-part-time: 2h
Theory classes: 2h

GRADING SYSTEM

- Written exam (60%) (exam week)
- Homework and deliverables: exercises and problem collection (40%) (to be delivered during the course)

BIBLIOGRAPHY

Basic:
- Yariv, A. Quantum electronics. 3rd. John Wiley and Sons, 1989. ISBN 9780471609971.
- Boyd, R. Nonlinear optics [on line]. 3rd. Boston: Academic Press, 2008 [Consultation: 27/05/2016]. Available on: http://www.sciencedirect.com/science/book/9780123694706. ISBN 9780123694706.
- Saleh, B.E.A.; Teich, M.C. Fundamentals of photonics. 3rd ed. Hoboken: John Wiley & Sons, 2019. ISBN 9781119506874.
- Akhmanov, S. A; Nikitin, S. Y. Physical optics. Oxford University Press, 1997. ISBN 0198517955.

Complementary:
- Shen, Y.R. The Principles of nonlinear optics. New York: John Wiley, 1984. ISBN 0471889989.
- Moloney, J.V.; Newell, A.C. Nonlinear optics. Boulder: Westview Press, 2004. ISBN 0813341183.

RESOURCES

Other resources:
Specific notes and guidelines on the virtual course ATENEA: slides, problem collection, scientific articles, etc.