Last update: 06-05-2019

230563 - NLO - Non-Linear Optics

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering

Teaching unit: 748 - FIS - Department of Physics

Academic year: 2019

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

ECTS credits: 3 Teaching languages: English

Teaching staff

Coordinator: Crina Cojocaru, UPC (coord).

Others: Jose Trull, UPC.

Opening hours

Timetable:

Degree competences to which the subject contributes

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.

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

230563 - NLO - Non-Linear Optics

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.

Teaching methodology

- Lectures

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

Total learning time: 75h	Hours large group:	24h	32.00%
	Self study:	51h	68.00%

Last update: 06-05-2019

230563 - NLO - Non-Linear Optics

Content

1. Maxwell equations and polarization

Learning time: 2h 48m
Theory classes: 2h 48m

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

2. Optics of Crystals

Learning time: 2h 48m
Theory classes: 2h 48m

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

3. Nonlinear polarization

Learning time: 2h 48m
Theory classes: 2h 48m

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

4. Nonlinear wave equations

Learning time: 2h 48m
Theory classes: 2h 48m

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

Last update: 06-05-2019

230563 - NLO - Non-Linear Optics

5. Second order nonlinear effects (plane wave approximation)	Learning time: 2h 48m Theory classes: 2h 48m

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)

6 Third order nonlinear effects (plane wave approximation)	Learning time: 2h 48m Theory classes: 2h 48m

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

7. Nonlinear optics with beams and pulses	Learning time: 1h 12m Theory classes: 1h 12m

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

Last update: 06-05-2019

230563 - NLO - Non-Linear Optics

8. Nonlinear light scattering and absorption	Learning time: 4h 30m Theory classes: 4h 30m

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

Planning of activities

Activity	Hours: 2h 18m Theory classes: 2h 18m

Qualification system

- Written exam (60%) (exam week)
- Homework: exercises and problem collection (30%) (to be delivered with the exam)
- Class and seminars attendance (10%)

Bibliography

Basic:

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.

Yariv, A. Quantum electronics. 3rd. John Wiley and Sons, 1989. ISBN 9780471609971.

Akhmanov, S. A; Nikitin, S. Y. Physical optics. Oxford University Press, 1997. ISBN 0198517955.

Saleh, B.E. A; Teich, M. C. Fundamentals of photonics. 2nd. John Wiley & Sons, 2007. ISBN 9780471358329.

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.