Course guides
230558 - EXPQO - Advanced Quantum Optics with Applications

Last modified: 03/06/2020

Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 893 - ICFO - Institute of Photonic Sciences.

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: Morgan W. Mitchell (ICFO) (Coord.)

Others: Hugues de Riedmatten (ICFO)

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.

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

CG2. (ENG) Màster en Fotònica:
Capacidad para la modelización, cálculo, simulación, desarrollo e implantación en centros de investigación, centros tecnológicos y empresas, particularmente en tareas de investigación, desarrollo e innovación en todos los ámbitos relacionados con la Fotónica.
CG4. (ENG) Màster en Fotònica:
Capacidad para entender el carácter generalista y multidisciplinario de la fótonica viendo su aplicación por ejemplo a la medicina, biología, energía, comunicaciones o la industria

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.
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.
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.

TEACHING METHODOLOGY

- Lectures
- Activities

LEARNING OBJECTIVES OF THE SUBJECT

This course presents the modern understanding of light as a quantum phenomenon, and explores how quantum applications such as quantum communications and quantum sensing are developed using quantum light. We describe optics at the individual-photon level, entangled and squeezed states of light, quantum non-locality, quantum memories and related advanced topics. The course gives necessary background for understanding contemporary experiments. Special attention is given to applications with atomic ensembles including quantum-enhanced sensing, and quantum memory.

STUDY LOAD

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

Total learning time: 75 h

CONTENTS

Issue 1

Description:
Quantization of the electromagnetic field

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

Issue 2

Description:
Estats quàntics de la llum: fotons individuals, estats coherents, estats 'squezzed', estats entrelligats.

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

Issue 3

Description:
Detection of quantum light: photon counting, coincidence counting, phase-sensitive detection.

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

Issue 4

Description:
Generation of quantum light by non-linear optical processes.

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

Tema 5

Description:
Experimental signatures of quantum behaviour.

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

Issue 6

Description:
Interaction of light with atomic ensembles.

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

Issue 7

Description:
Spin squeezing and quantum-enhanced measurements.

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

Issue 8

Description:
Experimental quantum communication: Quantum teleportation, entanglement swapping, quantum repeaters

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

Issue 9

Description:
Quantum memories based on Electro-magnetically Induced Transparency, Photon echoes, DLCZ.

Full-or-part-time: 2h 30m
Theory classes: 2h 30m

ACTIVITIES

Visit to ICFO laboratories

Full-or-part-time: 2h 18m
Theory classes: 2h 18m

GRADING SYSTEM

- Homework assignments and quizzes (45%)
- Final exam (45%)
- Participation and presentation (10%)

BIBLIOGRAPHY

Basic:
- Walls, D. F; Milburn, G. J. Quantum optics. 2nd. Springer-Verlag, 2008. ISBN 9783540285731.
- Scully, Marlan O; Zubairy, M. Suhail. Quantum optics. Cambridge University Press, 1997. ISBN 9780524235959.
- Loudon, R. The quantum theory of light. 3rd. Oxford Clarendon Press, 2001. ISBN 0198501765.

RESOURCES

Hyperlink:
- http://mitchellgroup.icfo.es/MEQO/. Notes of the course