

## 230558 - EXPQO - Advanced Quantum Optics with Applications

Coordinating unit:	230 - ETSETB - Barcelona School of Telecommunications Engineering
Teaching unit:	893 - ICFO - Institute of Photonic Sciences
Academic year:	2016
Degree:	ERASMUS MUNDUS MASTER'S DEGREE IN PHOTONICS ENGINEERING, NANOPHOTONICS AND BIOPHOTONICS (Syllabus 2010). (Teaching unit Optional) MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Teaching unit Optional)
ECTS credits:	3
Teaching languages:	English

### Teaching staff

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

Others: Hugues de Riedmatten (ICFO)

### 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.

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.

#### 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 fotonica según los procedimientos y convenciones de las presentaciones científicas en inglés.

#### General:

CG1. (ENG) Màster en Fotònica:

Capacidad para proyectar, diseñar e implantar productos, procesos, servicios e instalaciones en algunos ámbitos de la fotonica como los relacionados con la ingeniería fotonica, la nanofotonica, la óptica cuántica, las telecomunicaciones y la biofotonica

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 Fotonica.

CG4. (ENG) Màster en Fotònica:

Capacidad para entender el carácter generalista y multidisciplinario de la fotonica 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

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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
- 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

Total learning time: 75h	Hours large group:	22h 30m	30.00%
	Hours medium group:	0h	0.00%
	Hours small group:	0h	0.00%
	Guided activities:	2h 15m	3.00%
	Self study:	50h 15m	67.00%

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### Content

Issue 1	Learning time: 2h 30m Theory classes: 2h 30m
Description: Quantization of the electromagnetic field	
Issue 2	Learning time: 2h 30m Theory classes: 2h 30m
Description: Estats quàntics de la llum: fotons individuals, estats coherents, estats 'squeezed', estats entrelligats.	
Issue 3	Learning time: 2h 30m Theory classes: 2h 30m
Description: Detection of quantum light: photon counting, coincidence counting, phase-sensitive detection.	
Issue 4	Learning time: 2h 30m Theory classes: 2h 30m
Description: Generation of quantum light by non-linear optical processes.	
Tema 5	Learning time: 2h 30m Theory classes: 2h 30m
Description: Experimental signatures of quantum behaviour.	
Issue 6	Learning time: 2h 30m Theory classes: 2h 30m
Description: Interaction of light with atomic ensembles.	

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Issue 7	Learning time: 2h 30m Theory classes: 2h 30m
Description: Spin squeezing and quantum-enhanced measurements.	
Issue 8	Learning time: 2h 30m Theory classes: 2h 30m
Description: Experimental quantum communication: Quantum teleportation, entanglement swapping, quantum repeaters	
Issue 9	Learning time: 2h 30m Theory classes: 2h 30m
Description: Quantum memories based on Electro-magnetically Induced Transparency, Photon echoes, DLCZ.	

### Planning of activities

Visit to ICFO laboratories	Hours: 2h 18m Theory classes: 2h 18m
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### Qualification system

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

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### Bibliography

#### Basic:

Scully, Marlan O; Zubairy, M. Suhail. Quantum optics. Cambridge University Press, 1997. ISBN 9780524235959.

Walls, D. F; Milburn, G. J. Quantum optics. 2nd. Springer-Verlag, 2008. ISBN 9783540285731.

Loudon, R. The quantum theory of light. 3rd. Oxford Clarendon Press, 2001. ISBN 0198501765.

#### Others resources:

##### Hyperlink

<http://mitchellgroup.icfo.es/MEQO/>

Notes of the course