Course guide
230558 - EXPQO - Advanced Quantum Optics with Applications

Last modified: 26/05/2023

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).

Academic year: 2023 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: Consultar aquí / See here: https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/responsables-assignatura

Others: Consultar aquí / See here: https://telecos.upc.edu/ca/estudis/curs-actual/professorat-responsables-coordinadors/professorat-assignat-idioma

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 are developed using quantum light. We describe optics at the individual-photon level, entangled and squeezed states of light, and methods to observe quantum phenomena with light. The course gives necessary background for understanding contemporary experiments. Special attention is given to applications with atomic ensembles, e.g. quantum memory, quantum repeaters, and quantum networks.

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. Light as a quantum statistical phenomenon

Description:
• Quantum states of light
• Quantum light in optical systems
• Detection of quantum light
o Photon counting
o Time-correlated photon counting
o Phase-sensitive detection
• Generation of quantum states of light

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

2. Introduction to Quantum Communication

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

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

3. Generation and detection of single and entangled photons

Description:
• Photon pair generation by non-linear optical processes
• Experimental signatures of quantum behaviour.
• Single photon sources (quantum dots, color centers in diamond)
• Deterministic entanglement sources

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

4. Quantum teleportation and entanglement swapping

Description:
• Introduction to concept and protocols.
• Bell state measurement.
• Quantum repeaters and networks.

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

5. Quantum memories

Description:
• Quantum Light-Matter interfaces: single atoms, atomic ensembles, solid-state systems
• Major protocols: DLCZ, Electromagnetically induced, transparency, photon echo based protocols
• Decoherence in quantum memories
• Remote entanglement between quantum memories

Full-or-part-time: 7h
Theory classes: 7h

ACTIVITIES

Visit to ICFO laboratories

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

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