Course guide
230558 - EXPQO - Advanced Quantum Optics with Applications

Last modified: 14/12/2023

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. Demonstrate the understanding of the peculiarities of the quantum model for light-matter interaction.
CE9. Ability to synthesize and present photonics research results according to the procedures and conventions of scientific presentations in English.

Generical:
CG1. Ability to project, design and implement products, processes, services and facilities in some areas of photonics, such as photonic engineering, nanophotonics, quantum optics, telecommunications and biophotonics.
CG2. Ability to modeling, calculate, simulate, develop and implement in research and technological centers and companies, particularly in research, development and innovation tasks in all areas related to Photonics.
CG4. Ability to understand the generalist and multidisciplinary nature of photonics, seeing its application, for example, to medicine, biology, energy, communications or industry

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. Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context
CB7. Students should know how to apply the knowledge acquired and their problem-solving ability in new or little-known environments within broader (or multidisciplinary) contexts related to their area of ¿¿study.
CB8. Students should be able to integrate knowledge and face the complexity of formulating judgments based on information that, being incomplete or limited, includes reflections on the social and ethical responsibilities linked to the application of their knowledge and judgment.
CB10. Students should possess the learning skills that allow them to continue studying in a way that will be largely self-directed or autonomous.

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:
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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