Course guide
230588 - QINTERF - Quantum Light-Matter Interfaces: Modern Systems and Applications

Last modified: 26/05/2026

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 (Syllabus 2024). (Optional subject).

Academic year: 2026 **ECTS Credits:** 3.0 **Languages:** English

LECTURER

Coordinating lecturer: DAVID ARTIGAS GARCIA

Others: Primer quadrimestre:
DARRICK CHANG - 10

PRIOR SKILLS

It is recommended to have previously studied the course on "Quantum Optics"

TEACHING METHODOLOGY

1. Lectures where theoretical contents of the subject are presented.
2. Activities and problems related to the subject suggested by the teaching staff.

LEARNING OBJECTIVES OF THE SUBJECT

A. To gain familiarity with key platforms used to implement modern quantum atom-light interfaces, including cavity QED, free-space atomic ensembles, and atom arrays
B. To become familiar with the physical concepts and equations governing these systems
C. To understand major applications for these systems within quantum information science, and the fundamental limits of how well these applications can be executed in realistic systems.

STUDY LOAD

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

Total learning time: 75 h

CONTENTS

Single atom

Description:
1.1. Atom-light interaction Hamiltonian
1.2. Scattering cross section between single atom and single photon
1.3. Master equation descriptions of open systems
1.4. Possible routes to efficient atom-photon interactions
1.5. Key parameters: cavity cooperativity and optical depth

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

Cavity QED

Description:
2.1. Jaynes-Cummings model and dissipation
2.2. Single-photon generation efficiency and cooperativity
2.3. Input-output formalism
2.4. Photon-photon gates
2.5. Spin squeezing

Full-or-part-time: 6h
Theory classes: 6h

Atomic ensembles

Description:
3.1. Maxwell-Bloch equations
3.2. Optical depth
3.3. Electromagnetically induced transparency
3.4. Quantum memory
3.5. Rydberg interactions and photon-photon gates

Full-or-part-time: 6h
Theory classes: 6h

Sub-wavelength atom arrays

Description:
4.1. Motivation for this new paradigm
4.2. Theoretical "spin model" formalism
4.3. 2D array as a perfect mirror
4.4. Exponentially reduced errors in applications

Full-or-part-time: 6h
Theory classes: 6h

Overview of new quantum platforms

Description:
- Atom-nanophotonics interfaces
- Atom-nanophotonics interfaces
- Chiral atom-light interactions
- Atomic arrays
- Superconducting circuit quantum electrodynamics

Full-or-part-time: 4h
Theory classes: 4h

GRADING SYSTEM

1. Two presentations, performed in small groups, on contemporary research literature within the field of quantum atom-light interfaces. (80%)
2. Students' participation in class. (20%)

BIBLIOGRAPHY

Basic:
- Steck, Daniel Adam. Quantum and atom optics [on line]. 2007 [Consultation: 25/06/2021]. Available on: https://atomoptics-nas.uoregon.edu/~dsteck/teaching/quantum-optics/quantum-optics-notes.pdf.

RESOURCES

Other resources:
Typed lecture notes will be made available during the course.
Research Articles
Online resources (videos, etc)