

## Course guide

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

Last modified: 15/11/2022

**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:** 2022

**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>

## PRIOR SKILLS

It is recommended to have previously studied the courses on "Quantum Optics" and "Advanced Quantum Optics with Applications"

## TEACHING METHODOLOGY

- Lectures
- Activities

## LEARNING OBJECTIVES OF THE SUBJECT

Quantum light-matter interfaces are expected to constitute an important cornerstone for future quantum technologies. The objective of this course is to introduce students to the major experimental platforms being used today, including the historical workhorses of cavity QED and atomic ensembles, and upcoming paradigms such as atom-nanophotonic interfaces, quantum optomechanics, and superconducting circuit QED. We will also investigate in detail several important protocols for major applications within quantum technologies, such as quantum memories for light, photon-photon gates, coherent microwave-to-optical links, and quantum metrology, and understand the fundamental limits to how faithfully they can be implemented.

## STUDY LOAD

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

**Total learning time:** 75 h

## CONTENTS

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### Single atom

**Description:**

How efficient can the interaction of a single atom and photon be? And why does this motivate other approaches to attain efficient interactions?

**Full-or-part-time:** 2h

Theory classes: 2h

### Cavity QED

**Description:**

- Brief review of Jaynes-Cummings model, and introduction to key concepts of cavity cooperativity and photon blockade
- Input-output equation
- Major protocols and their limitations: quantum memory, single-photon generation, atom-photon and photon-photon gates, spin squeezing

**Full-or-part-time:** 6h

Theory classes: 6h

### Atomic ensembles

**Description:**

- Brief review of Maxwell-Bloch equations and the key concepts of collective enhancement and optical depth
- Major protocols and their limitations: quantum memory (electromagnetically induced transparency), spin squeezing
- A new approach to nonlinear optics: Rydberg atomic ensembles

**Full-or-part-time:** 6h

Theory classes: 6h

### Quantum optomechanics

**Description:**

- Introduction to canonical optomechanical Hamiltonian
- Major applications: quantum memory, quantum microwave-to-optical conversion, force sensing

**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

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- Homework assignments and quizzes (40%)
- Final exam (30%)
- Participation and presentations (30%)

## BIBLIOGRAPHY

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### 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>.