PHYS-454

Quantum optics and quantum information

Brantut Jean-Philippe

Cursus	Sem.	Type
Ing.-phys	MA2, MA4	Opt.
Minor in Quantum Science and Engineering	E	Opt.
Photonics minor	E	Opt.
Photonics		Opt.
Physicien	MA2, MA4	Opt.
Physics		Opt.
Quantum Science and Engineering	MA2, MA4	Opt.

Language of teaching	English
Credits	6
Session	Summer
Semester	Spring
Exam	Written
Workload	180h
Weeks	14
Hours	**4 weekly**
Courses	2 weekly
Exercises	2 weekly
Number of positions	

Summary

This lecture describes advanced concepts and applications of quantum optics. It emphasizes the connection with ongoing research, and with the fast growing field of quantum technologies. The topics cover some aspects of quantum information processing, quantum sensing and quantum simulation.

Content

1. Introduction
Review of two-level systems and harmonic oscillators.

2. Entanglement, decoherence and measurements
Density matrix of bipartite systems, entanglement, entanglement entropy, generalized measurements, system-meter description and POVMs, completely positive maps and Kraus theorem, quantum channels

3. Open quantum systems
Lindblad master equation, fundamental examples: Optical Bloch equations, damped harmonic oscillator. Stochastic Schrödinger equation, quantum state diffusion.

4. Mechanical effects of light and laser cooling
Motional effects on light-matter interactions, Doppler and recoil shifts, semi-classical forces on the two-level atom, Doppler cooling and magneto-optical traps, resolved sideband cooling.

5 - 6. Operation of quantum machines (two topics chosen among)
- Trapped ions quantum logic
- Rydberg quantum logic
- Collective effects in light-matter interactions and quantum metrology
- Digital and analogue quantum simulation

Learning Prerequisites

Required courses

Quantum Electrodynamics and quantum optics (Fall semester) or equivalent (see prerequisites below).

Important concepts to start the course

Good understanding of the two-level system and the harmonic oscillator in quantum mechanics, unitary transformations, canonical quantization of the electromagnetic field

Learning Outcomes

By the end of the course, the student must be able to:

- Perform calculations relevant to quantum optics
- Explore the scientific litterature in quantum optics and quantum information

Transversal skills

- Make an oral presentation.
- Use both general and domain specific IT resources and tools

Teaching methods

Video lectures, tutorials and exercise solved in the class, computer simulations. Mini-conferences with student presentations of research papers.

Assessment methods

Written examination

Resources

Bibliography

For a review of the basics of quantum optics

- Grynberg, Aspect and Fabre, *Introduction to Quantum Optics*

Core litterature for the course

- Haroche, Raimond, *Exploring the quantum*
- Chuang, Nielsen, *Quantum Computation and Quantum Information*

Further bibliographic elements on specific topics during the lectures and as exercises.

Ressources en bibliothèque

- Grynberg, Aspect and Fabre, Introduction to Quantum Optics
- Chuang, Nielsen, Quantum Computation and Quantum Information
- Haroche, Raimond, Exploring the quantum

Moodle Link

- https://go.epfl.ch/PHYS-454