PHYS-453

Quantum electrodynamics and quantum optics

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Cursus	Sem.	Type
Ing.-phys	MA1, MA3	Opt.
Minor in Quantum Science and Engineering	H	Opt.
Photonics minor	H	Opt.
Physicien	MA1, MA3	Opt.
Quantum Science and Engineering	MA1, MA3	Opt.

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

Summary

This course develops the quantum theory of electromagnetic radiation from the principles of quantum electrodynamics. It will cover historic developments (coherent states, squeezed states, quantum theory of spontaneous emission) and moreover modern developments, e.g. quantum noise and circuit QED

Content

- **Quantization of the electromagnetic field**
  - Week 1: Quantization of a Harmonic Oscillator, quantization of electrical circuits, field quantization
  - Week 2-3: Fock states, coherent states and squeezed states

- **Measuring the quantum States of Light**
  - Week 4: Phase space representations (Q-function, Wigner function, P-representation)
  - Week 5: Homodyne detection
  - Measurements, photon counting
  - Photon correlations, HBT effect, g(2) measurements

- **Superconducting circuits**
  - Week 6: Josephson Junctions
  - Cooper pair box and Transmon
  - Circuit quantization

- **Atom field interaction**
  - Week 7-8: Light matter interaction, dipole approximation, atom-field interaction Hamiltonian
  - Week 9: Quantum optics of an open cavity, Purcell effect
  - Cavity QED Hamiltonian
  - Week 10: Cavity quantum electrodynamics (cQED): strong coupling, dispersive regime
  - Applications of cQED: Generation of arbitrary quantum state of a harmonic oscillator, Quantum Metrology, QND

measurements of TLS

- **Introduction to quantum mesaurements**
  - Week 11: Quantum non-demolition measurements
  - Quantum backaction in linear measurements
  - Week 12: Quantum limits of interferometric measurements
  - Week 13: Pondermotive Squeezing
  - Week 14: Backaction-Evading Measurements
  - Quantum theory of an amplifier

- **Other topics covered: Recent developments in quantum optics, and use of Python Quantum Optical Toolbox to simulate open quantum systems**

Learning Prerequisites

Recommended courses

Quantum physics

Learning Outcomes

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

- Understand the quantum theory of electromagnetic radiation
- Understand the different effects of light-matter interaction
- Understand the differences of classical and quantum properties of light
- Use of Python toolbox to simulate open quantum systems
- Understand modern applications of quantum optics in quantum communication, quantum metrology and quantum computation

Teaching methods

Exercises (weekly).

Assessment methods

written exam

Resources

Moodle Link

- https://go.epfl.ch/PHYS-453