PHYS-453

Quantum electrodynamics and quantum optics

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Cursus	Sem.	Type
Electrical and Electronical Engineering	MA1, MA3	Opt.
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**
Lecture	2 weekly
Exercises	2 weekly
Number of positions	

Summary

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

Content

- **Coherent states, Quantization of a Harmonic Oscillator**
  - Quantization of the electromagnetic field, quantization of electrical circuits
  - Coherent states
  - Fock states
  - Squeezed states

- **Measuring the Quantum States of Light:**
  - Homodyne detection
  - Measurements, photon counting
  - Representations (Q-function, Wigner function, P-representation)

- **Photon correlations**
  - HBT effect, g(2) measurements

- **Strong coupling cavity QED.**
  - Light matter interaction, dipole approximation
  - Quantum description of a laser
  - Cavity QED Hamiltonian
  - Dispersive limit of cQED
  - Purcell effect

- **Applications of Cavity QED:**
    - Generation of arbitrary quantum state of a Harmonic oscillator
    - Quantum Metrology
    - Dispersive regime of cavity QED, QND measurements of Two level systems (qubits)

- **Quantum Nondemolition measurements (QND)**
    - Quantum backaction in linear measurements
    - The standard quantum limit (SQL)
    - Backaction evading measurements (BAE)

- **Quantum theory of an amplifier**
    - QLE approach to negative temperature
    - Noise temperature and added photons
    - Phase sensitive and phase insensitive amplification processes

- **Degenerate OPO and Squeezed light generation.**
    - Parametric amplification and squeezing using second harmonic generation

- **Stochastic Schroedinger Equation and Measurement theory**
- Quantum Jumps, quantum trajectories

- **Other topics covered: Recent developments in quantum optics (quantum metrology, quantum communication, etc.), 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