GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2024-2025

Quantum Optics (E006500)

Course size *(nominal values; actual values may depend on programme)*

Credits 6.0 **Study time 180 h**

Course offerings and teaching methods in academic year 2024-2025

A (semester 1)	English	Gent	seminar
			lecture
B (semester 1)	Dutch	Gent	

Lecturers in academic year 2024-2025

Kuyken, Bart	TWO5	lecturer-in-charge
Van Neck, Dimitri	WEO5	co-lecturer

Offered in the following programmes in 2024-2025	**crdts**	**offering**
Master of Science in Engineering Physics	6	B
Master of Science in Engineering Physics	6	A
Master of Science in Physics and Astronomy	6	A

Teaching languages

English, Dutch

Keywords

electromagnetic field, photons, quantization, (resonant) light-matter interaction, lasers, photon statistics, quantum information

Position of the course

The aim of this course is to provide a quantum mechanical treatment of the interaction between light and matter and apply it to various state-of-the-art applications such as lasers, single photon sources, cold atoms, quantum cryptography, quantum computing and quantum sensing.

Contents

1. Classical optics (3 sessions)
- Maxwell equations
- non-linear optics

2. Quantization of the radiation field (5 sessions)
- quantization of the free electromagnetic field
- coherent states and squeezed light
- Interaction of electromagnetic fields with matter
- Bose-Einstein condensation and polariton light sources

3. Lasers (3 sessions)
- quantum dots, quantum wells, VCSELs
- quantum cascade lasers
- practical aspects

4. Photon statistics (3 sessions)
- Poisson, super- and sub-Poissonian distributions
- photon annihilation and second order correlation
- single photon sources

5. Resonant light-matter interactions (3 sessions)
- two-level systems, weak and strong coupling
- Block sphere
- Purcell effect (application with LEDs and lasers)
- Strong coupling and Rabi oscillations

- Cold atoms: techniques and applications

6. Quantum information processes (5 sessions)
- Quantum cryptography
- Quantum computing
- Quantum sensing
- Entangled states and teleportation

Initial competences

Quantum Mechanics I & II, Electromagnetism I & II, Photonics, Solid State Physics

Final competences

1 Understand how the electromagnetic field can be quantized
2 Compute interaction properties of photons with matter in a full quantum picture
3 Understand the working principles and practical aspects of lasers
4 Understand the statistical properties of photons
5 Understand resonant light-matter interactions
6 Understand various quantum information processes
7 Overview of solid state photonic materials that enable photonic quantum applications

Conditions for credit contract

Access to this course unit via a credit contract is determined after successful competences assessment

Conditions for exam contract

This course unit cannot be taken via an exam contract

Teaching methods

Seminar, Lecture, Independent work

Study material

Type: Slides

Name: Learning material
Indicative price: Free or paid by faculty
Optional: no
Additional information: is provided on the university's electronic learning system.

References

- Walter Greiner: "Quantum Mechanics Special Chapters" (Springer-Verlag, Berlin Heidelberg 1998)
- Mark Fox, Quantum Optics: An Introduction (Oxford University Press 2006)
- Grynberg, Gilbert, Alain Aspect, and Claude Fabre. "Introduction to quantum optics." (Cambridge University Press 2010).

Course content-related study coaching

The instructor(s) can be contacted after the lectures, or by appointment.
Interactive support via the electronic learning platform

Assessment moments

end-of-term and continuous assessment

Examination methods in case of periodic assessment during the first examination period

Written assessment with open-ended questions

Examination methods in case of periodic assessment during the second examination period

Written assessment with open-ended questions

Examination methods in case of permanent assessment

Assignment

Possibilities of retake in case of permanent assessment

not applicable

Extra information on the examination methods

Both theoretical and exercise part of the exam with closed book A report about the current literature regarding Quantum Optics will be evaluated and accounts for 10% of the total grade

Calculation of the examination mark

The report accounts for 10% of the total grade