

## 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	TW05	lecturer-in-charge
Van Neck, Dimitri	WE05	co-lecturer

**Offered in the following programmes in 2024-2025**

	<b>crdts</b>	<b>offering</b>
<a href="#">Master of Science in Engineering Physics</a>	6	B
<a href="#">Master of Science in Engineering Physics</a>	6	A
<a href="#">Master of Science in Physics and Astronomy</a>	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
  - Bloch 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

