GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2019-2020

Lasers (E030660)

Due to Covid 19, the education and evaluation methods may vary from the information displayed in the schedules and course details. Any changes will be communicated on Ufora.

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

Credits 4.0 **Study time 120 h** **Contact hrs** 30.0 h

Course offerings and teaching methods in academic year 2021-2022

A (semester 1)	English	Gent	seminar: coached exercises	7.5 h
			lecture	22.5 h
O (semester 1)				

Lecturers in academic year 2021-2022

Morthier, Geert	TW05	lecturer-in-charge
Le Thomas, Nicolas	TW05	co-lecturer
Verschaffelt, Guy	VUB	co-lecturer

Offered in the following programmes in 2021-2022	crdts	offering
Bridging Programme Master of Science in Photonics Engineering	4	A
Master of Science in Electrical Engineering (main subject Communication and Information Technology)	4	A
Master of Science in Electromechanical Engineering (main subject Control Engineering and Automation)	4	A
Master of Science in Electromechanical Engineering (main subject Electrical Power Engineering)	4	A
Master of Science in Electrical Engineering (main subject Electronic Circuits and Systems)	4	A
Master of Science in Electromechanical Engineering (main subject Maritime Engineering)	4	A
Master of Science in Electromechanical Engineering (main subject Mechanical Construction)	4	A
Master of Science in Electromechanical Engineering (main subject Mechanical Energy Engineering)	4	A
European Master of Science in Photonics	4	A
Master of Science in Photonics Engineering	4	A, O

Teaching languages

English

Keywords

resonators, laser theory, laser beams, laser types

Position of the course

Since their invention in 1960, lasers have become the most important light sources in optics and photonics, and are present everywhere in modern society nowadays. For example, worldwide telecommunication is based on the transmission of laser signals through optical fibers, and today's manufacturing industry heavily relies on the use of high-irradiance laser beams. Other application domains include medicine, art restoration, remote sensing, biological spectroscopy, and many others. It is the general aim of this course that the students will become able to explain and analyse laser properties and laser-related concepts, that they learn to construct and analyse the mathematical description of important concepts, and that they are also able to apply the latter to practical examples on the use of lasers.

Contents

1 CHAPTER 1: THE BASICS

- Basic laser physics: Introduction; Absorption; Spontaneous and stimulated emission of

- light; Amplification; Basic laser setup; Gain, saturation and line broadening
- Basic properties of laser light: One direction; One frequency; One phase; Laser light is intense

2 CHAPTER 2: LASER THEORY
- Introduction: The need for more than two energy levels; Rate equations for a 4-level laser
- Continuous-wave (cw) laser action: Output power in cw regime; Influence of experimental parameters; Transients
- Pulsed laser action: Introduction; Gain switching; Q-switching; Cavity dumping; Mode-locking; Ultra-short pulses

3 CHAPTER 3: LASER RESONATORS AND THEIR MODES
- Introduction
- Modes in a confocal resonator: Wave fronts; Frequencies; Transverse light distribution
- Modes in a non-confocal resonator: Stability criteria; Frequencies
- Modes in a waveguide resonator: Modes in a fiber waveguide resonator; Modes in an on-chip waveguide resonator
- Modes in a (free-space/waveguide) ring resonator
- Modes in a real laser: Line broadening; Selection of modes
- Saturation and hole-burning effects: Spatial hole burning; Spectral hole burning

4 CHAPTER 4: LASER BEAMS
- Gaussian beams: Basic Formulas; Propagation; Transformation by a lens and focusing; Transmission through a circular aperture
- Multimode beams: Introduction; Spot radius *W* for a multimode beam; Beam Propagation Factor *M*; A more theoretical approach; Practical use

5 CHAPTER 5: TYPES OF LASERS
- General introduction
- Gas lasers: General; Neutral gas (He-Ne); Ionized gas (argon ion); Molecules (CO_2); Excimer lasers (ArF)
- Liquid lasers (dye laser)
- Solid-state lasers: General; Rare-earth-doped lasers (Nd:YAG and Er:fiber); Transition-metal-doped lasers (Ti: Sapphire); Changing the wavelength by optical nonlinear effects
- Other lasing mechanisms: Raman lasing

6 CHAPTER 6: LASER DIODES: OPERATION PRINCIPLES:
- Geometry and important characteristics
- Material aspects: heterostructures, gain and absorption, low dimensional materials, gain saturation, ...
- Fabry-Perot laser diodes: cavity resonance
- Fabry-Perot laser diodes: dynamic operation: Rate equations, Dynamic operation, Noise: power spectrum and phase noise, Injection locking
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7 CHAPTER 7: OVERVIEW OF SEMICONDUCTOR LASER TYPES:
- Distributed Feedback and Distributed Bragg Reflector laser diodes
- Vertical Cavity Surface Emitting Laser diodes
- Tunable laser diodes
- Quantum Cascade lasers
- Laser diode packaging

Initial competences

introductory photonics course

Final competences

1 The students are able to name, describe and explain laser properties and concepts, including: spontaneous and stimulated emission, absorption, coherence, light propagation in resonators, continuous-wave and pulsed laser action, line broadening, saturation, Gaussian laser beams, operation and applications of different laser types (gas lasers, liquid lasers, solid-state lasers, semiconductor lasers), laser dynamics, intensity noise and phase noise, Bragg gratings, wavelength tuning, packaging of laser diodes.

2 The students have the ability to derive from first principles the mathematical description for laser-related concepts, including: rate equations describing the general operation principle of laser action and formulas for continuous-wave/pulsed laser action, formulas for the modes in different types of resonators with different stability criteria, equations for propagation and transformation of Gaussian and multimode laser beams in optical systems, laser rate

equations of semiconductor lasers, formulas for the dynamic behaviour of lasers, description of spontaneous emission noise, formulas for laser diode linewidth.

3 The students know how to explain and analyse the above-enlisted mathematical descriptions for laser-related concepts.

4 The students are able to apply the above-enlisted mathematical descriptions to practical examples and to use these descriptions to solve practical problems.

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

Lecture, seminar: coached exercises

Learning materials and price

lecture notes + slides (in English)
Exercise sheets are provided during the lectures

References

Optional: O. Svelto, Principles of Lasers (4th Edition), Plenum Press, New York.

Course content-related study coaching

Evaluation methods

end-of-term evaluation

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

Oral examination

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

Oral examination

Examination methods in case of permanent evaluation

Possibilities of retake in case of permanent evaluation

not applicable

Extra information on the examination methods

During examination period: oral closed-book exam, written preparation. The exam will always cover the 2 parts of this course (lasers and semiconductor lasers). Partial transfer of the score obtained for an individual part to the 2nd session or the next academic year is not allowed.

Calculation of the examination mark