Course Specifications

Valid as from the academic year 2020-2021

Photonic Integrated Circuits (E030790)

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 2020-2021

A (semester 2)	English	Gent	project	8.75 h
			seminar: coached exercises	15.0 h
			lecture	6.25 h

Lecturers in academic year 2020-2021

Bogaerts, Wim	TW05	lecturer-in-charge

Offered in the following programmes in 2020-2021	crdts	offering
European Master of Science in Photonics	4	A

Teaching languages

English

Keywords

photonic integrated circuits, waveguides, silicon photonics, design, simulation

Position of the course

This course goes in depth into the topic of photonic integrated circuits, building on the concepts taught in courses like photonics, microphotonics and semiconductor photonics devices. The course focuses on how to design and simulate photonic ICs. It takes a hands-on approach where the students will design a small photonic circuit that will be actually fabricated and measured for analysis. Design of individual components (building blocks) will be covered, as well as circuit design and wavelength filters.

Contents

Sessions would generally comprise of a short ex-cathedra presentation (30-45 minutes), and then hands-on exercises with design tools. Through the course, the students will make a design that will be fabricated (using UGent's e-beam or an external rapid prototyping service) and measured using the UGent automated measurement setup. They will have to analyze the result in the end and compare it to their original circuit specifications.

- Introduction: basic concepts in photonic ICs (components vs. circuits). Design flows (comparison with EDA). Principles of PDK (process design kits), MPW (multi-project wafer services), tape-outs. Overview of the rest of the course. (1 session)
- Circuit design: PDK-driven: From design capture (schematic) and simulation over place-and-autoroute to a circuit. Using standard components from a library, build a simple passive filter circuit like a resonator or Mach-Zehnder interferometer (MZI). Using parametric cells in a standard design tool. Basic circuit simulation. This device is the basis of the project work and will be taped out for fabrication. (2 sessions)
- Waveguides and Material systems: What is the basic operational principle of an optical waveguide? How does the choice of materials (and the refractive index contrast) affects the performance of the waveguide? What are the available material systems for photonic integrated circuits, and what are their strengths and weaknesses? (1 session)
- Component design: Parts of a component description. Going from specification to an implementation. Constructing parametric cells. Different simulation techniques/solvers and when to use them. Application in the design of a splitter, resonator, multi-mode interferometer (MMI), grating coupler. (2 sessions)
- Filter design: How do wavelength filters work? Different types of filters (IIR, FIR) and implementations (arrayed waveguide grating, Echelle grating, MZI, ...). Synthesize

- an optical filter from functional requirements. (1 session)
- From Component to Circuits: Surrogate and compact models. Different ways to describe components (frequency/time domain). Defining relevant models, choosing parameters and typical pitfalls. Hands-on constructing a model description for a component, building up complexity (dispersion, parasitics, ...). (1 session)
- Optimizations: different ways to optimize a component: numerical, surrogate model based, or experimental. Includes basics of DOE. Application in designing a component or small subcircuit. (1 session)
- Design for manufacturability: Concepts of design rules and verifications, impact of lithography processes on components and circuits. Different types of variability (Wafer-to-wafer, intra-wafer and intra-die) and their causes. Corner analysis and yield prediction using monte-carlo circuit simulations. Approaches to tolerant designs (robust optimization, passive compensation). (1 session)
- Measurement and data-analysis: Basic measurement principles (but no hands-on-measurement). Measurement errors and variability. Fitting and parameter extraction. Apply on the measurements of the fabricated devices. (1 session)
- Applications: What are photonic integrated circuits used for? What are the different boundary conditionsfor the various applications in communications, sensing, measurement techniques etc. ? (1 session)

Initial competences

- Electromagnetics;
- Course of Microphotonics: understanding of optical waveguides and waveguiding components (directional couplers, taper, splitter), basic simulation methods.

Final competences

1. Understanding of the PIC design flow and tape-out flow and the potential obstacles.
2. Understand different simulation techniques and know which problems to apply them to.
3. Design basic integrated optical filters from functional specifications.
4. Understanding of nonidealities in photonic chips and circuits.
5. Generate correct mask files for an optical chip.

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, project, seminar: coached exercises

Extra information on the teaching methods

Lectures, coached exercises, project work

Learning materials and price

Slides and interactive notebooks: Jupyter notebooks are ideally suited for interactive, education labs. They support a variety of languages, but Python is the most popular (others are R and Ruby), and it has very strong scientific and engineering libraries.

References

Course content-related study coaching

Evaluation methods

end-of-term evaluation and continuous assessment

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

Written examination, oral examination

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

Written examination, oral examination

Examination methods in case of permanent evaluation

Report

Possibilities of retake in case of permanent evaluation

examination during the second examination period is possible in modified form

Extra information on the examination methods

- End of term examination (written and oral)
- Continuous assessment (exercises, report)

Calculation of the examination mark

50% on excercises and project work;
50% on end of term examination.