GHENT UNIVERSITY

Course Specifications

Valid as from the academic year 2025-2026

Theory of Photonic Integrated Circuits (E030420)

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

Credits 6.0 **Study time 180 h**

Course offerings in academic year 2025-2026

A (semester 1)	English	Gent

Lecturers in academic year 2025-2026

Van Thourhout, Dries	TW05	lecturer-in-charge
Bienstman, Peter	TW05	co-lecturer
Curto, Alberto	TW05	co-lecturer

Offered in the following programmes in 2025-2026	**crdts**	**offering**
Master of Science in Silicon Photonics	6	A

Teaching languages

English

Keywords

PICs, waveguides, numerical methods for photonics

Position of the course

Expose the students to various fundamental concepts necessary to understand PICs

Contents

1 Maxwell's equations: a rehearsal
2 Waveguide modes (1)
  1 Wave equation for uniform waveguides
  2 Properties of waveguide modes
    1 Propagation constant, effective index
  3 Solving the equation
    1 Effective index method
    2 Numerical methods (Reference to related chapter)
  4 Bend modes (based on conformal transformation)
  5 Complement:
    1 Slab waveguide
    2 General conformal transformation
3 Matrix descriptions of wave propagation in linear systems:
  1 Transfer matrices and S-matrices (bidirectional),
  2 Representation of light polarisation (Jones, Stokes, Poincare),
  3 Jones matrices
4 Waveguide components
  1 Eigenmode propagation
  2 Application note: MMI
  3 Coupled mode theory
  4 Uniform codirectional
  5 Directional coupler
  6 Periodic codirectional
  7 Contradirectional
  8 Adiabatic tapers
  9 Taper criterium
  10 Edge couplers
  11 Vertical coupling

5 Periodic structures (2)
  1 Low index contrast
  2 Bragg-equation, in volume, at surfaces
  3 K-Vector diagram
  4 Grating coupler
  5 High index contrast
  6 Solution through Floquet Bloch
  7 Strong gratings & Photonic crystals
  8 Subwavelength gratings
6 Resonators (2)
  1 General theory (Q-factor, Finesse, FSR, ...)
  2 Ring resonators
  3 Coupled resonators
  4 Applications
7 Plasmonics (1)
  1 Bulk plasmon polariton (concept)
  2 Surface plasmon
  3 Gap plasmon
  4 Localized plasmons (Rayleigh vs. Mie Theory)
8 Advanced components (1)
  1 MZI
  2 AWG (with link to Fourier Optics)
  3 PCG
  4 Add-drop multiplexers
9 Numerical methods for photonics (1)
  1 FD
  2 FE
  3 Eigenmode expansion
  4 FDTD
  5 RCWA
  6 Band diagrams
10 Special topics
  1 Study a paper related the concepts discussed in previous chapters (e.g. a basic paper on cavity optomechanics)

Initial competences

Basic optics and electromagnetics

Final competences

1 Understand the basic physics underlying propagation of light in optical waveguides and photonic integrated circuits
2 Understand the operation principles and design rules for basic components such as bends, fiber chip couplers, splitters and filters
3 Get insight in the main parameters describing the operation of optical cavities
4 Understand the principles underlying propagation of light in waveguides with a periodic perturbation and photonic crystals
5 Understand how the interaction of light and metals can lead to increased confinement and new physical effects
6 Understand the basic principles of the numerical methods used for designing photonic integrated circuits
7 Analyse complex photonic integrated circuits

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

Extra information on the teaching methods

- Short video's separated at first sublevel (a), b), c))
- Lectures: answering questions, solving exercises
- Additional:
  - Homework exercises (marked)

- CAD-labs

Study material

Type: Slides

Name: Slides and course notes used during the course
Indicative price: € 11
Optional: no
Additional information: Available electronically (free) or through the student organization (8 /11,5 Euro member/non-member)

References

- Current courses Microphotonics, Advanced Electronic and Photonic Devices
- Introduction to Nanophotonics, H. Benisty, J. J. Greffet, P. Lalanne, Oxford Gratudate Texts

Course content-related study coaching

Assessment moments

end-of-term and continuous assessment

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

Oral assessment, Written assessment open-book

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

Oral assessment, Written assessment open-book

Examination methods in case of permanent assessment

Assignment

Possibilities of retake in case of permanent assessment

examination during the second examination period is possible in modified form

Extra information on the examination methods

- During examination period: written open-book assessment and oral closed-book assessment.
- During semester: graded homework.

Calculation of the examination mark

Special conditions: project based on a number of CAD-sessions: 30%. Exam: 70%.