UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Mathematical and Computational Methods for Optics

2425-1-F1702Q006

Aims

Acquire a basic knowledge of Python programming language. Learn the basic mathematical methods and tools needed for the rigorous description of physical phenomena in geometric and Fourier optics. Carry out an elementary training on ray-tracing software (such as Zemax) to practically set up, design and analyse simple optical systems.

Contents

? Module I – Introduction to Python Programming Language. Basic coding in Python with applications in optics

? Module II – Introduction to Fourier optics: mathematical tools, physical principles and applications

? Module III - Computer-aided optical system modelling, analysis and design. Basic use of ZEMAX designing software for Optics simulations

Detailed program

? Introduction to the course and its structure

? Module I – Introduction to Python Programming Language:

- Interactive Programming Environments
- Type of variables, strings and expressions

- Type conversion, print and input
- Conditional statements: If, elif and else instructions
- Cycles: while and for
- Lists
- Dictionaries
- Python functions: examples
- Modules of Python Standard Library
- Data visualization
- Computer Lab: Python Basic programs (including import of Scientific libraries), with applications in optics

? Module II – Introduction to Fourier optics: mathematical tools, physical principles and applications

- Mathematical concepts (definition, properties, interpretation, …) of Fourier analysis:
  o Fourier series
  o Fourier Transforms and Antitransforms
  o Convolution
  o Examples of Fourier transforms
- Physical concepts:
  o Review on kinds of waves: monochromatic waves, plane waves, spherical waves
  o Diffraction: Huyghens-Fresnel principle, Fresnel and paraxial approximation, Fraunhofer approximation
  o Optical transfer function (OTF), modulation transform function (MTF), point spread function (PSF)
- Combination of the previous mathematical and physical concepts for applications and examples in optics: lenses, filters

? Module III - Computer-aided optical system modelling, analysis and design

- Ray-tracing in optics: Principles, definitions, algorithm and examples (spherical surfaces, glasses, …)
- How to model a lens in a computer
- Stops, pupils, etc
- Brief overview of optical aberrations and methods for their compensation
- Sequential analysis of an optical system
- Study of the MTF of an optical system and its relationship with spatial resolution
- Non-sequential analysis of optical systems
- Examples of modeling using Physical Optics
- Computer Lab: Practical computational training with ANSYS ZEMAX OpticStudio for Ray-tracing simulations. Applications to selected optical systems

Prerequisites

Appropriate mastering of the following contents:

Numerical sets (natural, integer, rational, real and complex numbers). Functions of one real variable, limits, continuity, differentiability. Derivative of a function. Riemann integral and improper integral. Elementary notions of ordinary differential equations. Sequences and series. Linear algebra. Differential calculus in several variables. Line integrals. Integral calculus in several variables. Basic concepts of geometrical and physical optics.

Teaching form

- Front lessons on theoretical concepts: 26 hours in-person + 10 hours at distance;
- Exercises on how to apply the theory concepts to practical optics problems: 4 hours in-person;
- Computational laboratory with Python and ZEMAX optics software: 12 hours at distance.

Lessons will be videorecorded and available on the elearning page of the course.

Textbook and teaching resource

- Slides provided by the teacher
- G. J. Gbur, “Mathematical Methods for Optical Physics and Engineering”, Editor: Cambridge University Press (2011)
- J.W. Goodman, “Introduction to Fourier Optics”, Editor: W. H. freeman, Macmillan Learning (2017) (or any other editions)
- J. D. Gaskill, “Linear Systems, Fourier Transforms, and Optics”, Editor: John Wiley & Sons (1978)

Semester

second semester

Assessment method

The assessment will be based on a written test (with open questions and exercises on module II) and an oral exam (which consists in i) one or more computational exercises to be solved at the moment via Python and/or using the optical design software, ii) a discussion of the written exam). The oral exam can be taken only if the written test is sufficient (grade >= 18 out of thirty). The final evaluation will be evaluated as the average of the written and oral exam, rounded to the closest integer. No intermediate exams will be carried out. Students are required to master the topics of the course and the capability to face mathematical and computational problems dealing with optics.

Office hours

by appointment arranged via email

Sustainable Development Goals

GOOD HEALTH AND WELL-BEING | INDUSTRY, INNOVATION AND INFRASTRUCTURE