UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Optical Microscopy

2627-1-F1703Q030

Aims

1. Knowledge and understanding.
The student will acquire advanced knowledge in geometrical and physical optics, including:
-propagation of electromagnetic energy,
-reflection and refraction (Fresnel coefficients),
-optics of thin and thick lenses,
-principles of wave optics (Huygens-Fresnel),
-applications of the Fresnel integral,
-Fourier optics and advanced microscopy techniques (e.g., confocal, multiphoton, SHG, CARS).
Core concepts and theoretical-experimental tools will be explored in depth to enable understanding and analysis of optical systems.

2. Applying knowledge and understanding.
By the end of the course, the student will be able to:
-apply optical models to analyze and design systems and devices,
-use matrix formalism for lenses and mirrors,
-compute the propagation of laser beams,
-estimate resolution, magnification, and optical aberrations,
-understand the operation of complex optical instruments,
-interpret images and data obtained through optical microscopy techniques.

3. Making judgements.
The student will develop:
-critical skills in selecting appropriate models for the analysis of optical phenomena,
-autonomy in evaluating the behavior of optical components (lenses, mirrors, fibers),
-awareness of the limitations of instruments and aberration correction techniques,
-the ability to assess the quality and reliability of optical systems in experimental and applied contexts,
-critical judgment in selecting the most suitable optical microscopy technique for different applications.

4. Communication skills.
The student will be able to:
-clearly and rigorously present concepts in geometrical and physical optics,
-correctly use technical terminology in educational and professional contexts,
-collaborate effectively within multidisciplinary teams in the fields of photonics and imaging.

5. Learning skills.
The student will acquire:
-methodological tools to independently deepen advanced topics in optics,
-skills in consulting scientific texts and specialized articles,
-competencies to undertake further specialization (advanced courses, thesis work, laboratory or research activities).

Contents

Geometrical Optics: lenses, mirrors and compositions of lenses and stops.

Physical Optics: Fresnel Theorem and its applications.

Aberrations of optical devices

Scanning Optical Microscopies.

Digital Pathology.

Detailed program

- Electromagnetic energy, intensity with lasers in continuous and pulsed emission mode.

- Fresnel coefficients for reflection and refraction: phenomenology; the retarder plates.

- Introduction to "Fresnel Coefficients and Maxwell equations".

- Law of the prism in minimal deviation (geometical and physical optics treatment), relation with the thin lens.

- The law of focal lengths for thin lenses. Composition of thin lenses.

- The matrix method for lenses and mirrors and its applications to optical instruments.

- Thick lens. Principal planes and the focal length. Magnification of an optical system.

- Principal aberrations of lens systems: phenomenology and Seidel treatment.

- Aberration correction.

- Introduction to Physical Optics, Huygens-Fresnel principle and Fresnel Integral.

- Applications of the Fresnel integral: Fresnel zones, Gaussian beam propagation.

- Applications of the Fresnel theorem: Fourier optics and spatial filtering.

- Optical fibers: geometric and physical optics treatment.

- Optical resolution

- Optical Microscopy techniques (Confocal Microscopy, Multi-photon Microscopy, Second Harmonic Generation Microscopy, Brighfield and darkfield, Coherent Anti-Stokes Raman Microscopy, Digital Pathology, Hyperspectral Imaging, Phasor-based image analysis).

Prerequisites

Knowledge of electromagnetic waves and of the mathematical treatment of the wave equation.

Knowledge of the fundamentals of the light-matter interactions modes.

Skills: solution of partial derivatives equations; trigonometry.

Teaching form

Frontal Lectures in Italian with slides in power point (Instructional teaching):
21 two-hour lessons delivered in frontal teaching mode.

Discussion of problems.

Assignment of home excercises

Reading and discussion of research papers.

Textbook and teaching resource

Copy of the slides discussed during the lectures loaded on the e-learning platform.

Indication of the web sites with information on specific applications and Java simulations.

Books:

- "Optics". Klein

- "Optics". Hecht

- "Introduction to optical microscopy". Mertz

- "Introduction to Fourier Optics". Goodman

Semester

Second semester of the Master Degree

Assessment method

ORAL EXAM RELATED TO TOPICS ILLUSTRATED DURING THE LESSONS AND TO SUPPLEMENTARY TOPICS NOT DISCUSSED DURING LESSONS.

In particular, the exam will be related to the following topics:

1. basic principles of the construction of an optical device and its discussion based on the matrix method;

2. basic princpiles of Fourier Optics;

3. resolution of an optical device in wide field and in scanning modes;

4. discussion of a research paper (with an optional slide presentation), related to topics not covered during frontal lessons.

There are no partial tests. The final grade will be determined by:
-the evaluation of the discussion of the paper related to topics not covered during the lessons
-the evaluation of the knowledge of the different topics covered during the frontal lessons

Regarding the grading scale: the oral exam is graded on a 30-point scale. Particular emphasis will be placed on the student's ability to understand and explain the requested topic (whether chosen by the student or covered during the lectures), both in terms of describing experimental setups and outlining the theoretical framework. Additionally, the following will be assessed:
-the use of appropriate technical terminology
-the ability to present concepts in a clear, logical, and coherent manner
-the command of scientific language

Office hours

Usually the teacher is always available for reception, however the presence is guaranteed only if previously arranged, either in classroom or by e-mail.

Sustainable Development Goals

QUALITY EDUCATION | GENDER EQUALITY | DECENT WORK AND ECONOMIC GROWTH | INDUSTRY, INNOVATION AND INFRASTRUCTURE | PARTNERSHIPS FOR THE GOALS