

**COURSE OF STUDY** *Physics (LM-17)*
**ACADEMIC YEAR** 2023-2024

**ACADEMIC SUBJECT** *Laboratory of Photonics*

General information	
Year of the course	1st
Academic calendar (starting and ending date)	2 <sup>nd</sup> semester: March – May 2024
Credits (CFU/ECTS):	6
SSD	FIS/03
Language	English
Mode of attendance	Compulsory

Professor/ Lecturer	
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Virtual room	gjoifyk
Office Hours (and modalities: e.g., by appointment, on line, etc.)	Mon & Wed from 3 to 4 pm, office and online

Work schedule			
Hours			
Total	Lectures	Hands-on (laboratory, workshops, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
150	32	30	88
CFU/ECTS			
6	4	2	

<b>Learning Objectives</b>	Skills in modern geometrical and classical optics, laser beams characterization and shaping, both on theoretical and practical basis. Knowledge of light propagation in free-space and linear optical components.
<b>Course prerequisites</b>	Electromagnetism and waves, ray optics, laser fundamentals, differential calculus and complex functions

<b>Teaching strategies</b>	Frontal teaching using slides and blackboard. Laboratory activities: group work for the preparation for laboratory activities, the conduct of experiments, and the discussion and critical analysis of the results. Report of lab experiences
<b>Expected learning outcomes in terms of</b>	
<b>Knowledge and understanding on:</b>	<ul style="list-style-type: none"> <li>o Understanding the scientific method, the nature, and the methods of research in Physics</li> <li>o Knowledge of the structure of matter, with particular attention to condensed matter and photonics applications</li> <li>o Advanced geometrical optics</li> <li>o Properties of Gaussian beam and the way to characterize it</li> <li>o Polarization optics</li> <li>o Statistical properties of light</li> </ul>

	<ul style="list-style-type: none"> <li>o Light propagation and Fourier optics</li> <li>o Designing tools for tailoring optical properties</li> </ul>
<b>Applying knowledge and understanding on:</b>	<ul style="list-style-type: none"> <li>o Ability to identify the essential elements of a phenomenon</li> <li>o Ability to use analogy to apply known solutions to new problems (problem solving)</li> <li>o Ability to use analytical and numerical mathematical computation tools</li> <li>o Criteria for choosing optical materials and components.</li> <li>o Criteria for choosing instrumentation for light beams characterization.</li> </ul>
<b>Soft skills</b>	<ul style="list-style-type: none"> <li>● <b>Making informed judgments and choices</b> <ul style="list-style-type: none"> <li>o Ability to work with increasing levels of autonomy, including taking responsibility in project planning and managing facilities</li> <li>o Judge the value of acquired knowledge. Establish evaluation criteria and standards, both quantitative and qualitative</li> <li>o Compare, contrast, distinguish, describe novel technologies and the underlying physical phenomena</li> </ul> </li> <li>● <b>Communicating knowledge and understanding</b> <ul style="list-style-type: none"> <li>o Competence in communication in Italian and English in advanced fields of Physics</li> <li>o Writing extended laboratory reports.</li> <li>o Preparing and presenting tutorial-type presentations.</li> </ul> </li> <li>● <b>Capacities to continue learning</b> <ul style="list-style-type: none"> <li>o Acquisition of basic knowledge tools for continuous learning and knowledge updates</li> <li>o Critically review laboratory results.</li> </ul> </li> </ul>
<b>Syllabus</b>	
<b>Content knowledge</b>	<p><b>Matrix geometric optics and Gaussian beams</b>  Matrix geometric optics  Elementary solutions of the Gaussian wave equation and beams  ABCD matrices and beam shaping</p> <p><b>Vector optics</b>  Brief review of the e.m. theory of the light  Linear, circular and elliptical polarization; Malus law  Polarization and matrix representation (Jones and Muller matrices)  Polarization by scattering and reflection, Fresnel relations  Birefringence and waveplates  Partial polarization (Stokes parameters, degree of polarization, Poincaré sphere)</p> <p><b>Interference and coherence</b>  General considerations and conditions for interference  Interference between 2 beams of light and its applications (interferometric measurements and Optical Coherence Tomography)  Interference between multiple beams and its applications (diffraction gratings, Fabry-Perot, antireflection coatings, interferential filters)  Overview of Statistical Optics: function of mutual coherence, degree of coherence</p> <p><b>Fourier optics</b>  Brief review of Fourier transforms and linear systems  Plane-wave and spatial harmonics  Fraunhofer diffraction (single and double slits, circular slit, diffraction gratings)  Fresnel Diffraction (openings and circular obstacles, Fresnel plate)  Transfer functions and impulse-response function  Optical Fourier transforms and imaging  Spatial filters</p> <p><b>Optical instrumentation</b>  Linear optical components and systems: main features and criteria for selection</p> <p><b>Laboratory experiences</b>  1. Laser fluorometer (in CW) and construction of a spectrometer</p>

	<p>2. Polarization: Malus's Law and its consequences; use of waveplates and measurement of Stokes parameters</p> <p>3. Michelson interferometer and low coherence interferometry: measurement of the refractive index of a medium; measurement of the coherence time of a LED; operating principle of OCT</p> <p>4. Diffraction: single and double slit, circular slit, diffraction grating, spiral obstacle</p> <p>5. Microscopy and Fourier optics</p>
<b>Texts and readings</b>	<p>G. Benenti, G. Casati, D. Rossini, G. Strini, Principles of quantum computation and information (World Scientific, 2019).</p> <p>M. A. Nielsen and I. L Chuang, Quantum computation and quantum information (Cambridge University Press, 2010).</p>
<b>Notes, additional materials</b>	
<b>Repository</b>	

<b>Assessment</b>	
Assessment methods	Lab report and oral exam
Assessment criteria	<ul style="list-style-type: none"> <li>● <b>Knowledge and understanding</b> Minimum: the properties of Gaussian beam and the way to characterize it, classification and usage of optical materials. Intermediate: materials' design tools for tailoring optical properties. Optimal: maths of wave propagation in transparent media.</li> <li>● <b>Applying knowledge and understanding</b> Minimum: critical analysis and accurate presentation of laboratory activity Intermediate: comprehensive review of state-of-art Optimal: comparison of experimental data with numerical simulations</li> <li>● <b>Autonomy of judgment</b> Minimum: correct estimation of experimental uncertainties. Intermediate: motivated choice of materials and components for the purpose. Optimal: identification of the optimal setup for a given measurement.</li> <li>● <b>Communicating knowledge and understanding</b> Minimum: compliance with timing and template of reports and presentation. Intermediate: cogency of argumentation. Optimal: skillful presentation of state-of-art and perspective studies</li> </ul>
Final exam and grading criteria	20% lab reports, 80% oral exam (20% for each of the above criteria)
<b>Further information</b>	
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