Course guide
230551 - LAB - Photonics Laboratory

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Unit in charge: Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics.

Degree: MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Compulsory subject).

Academic year: 2025 **ECTS Credits:** 5.0 **Languages:** English

LECTURER

Coordinating lecturer: JOSE FRANCISCO TRULL SILVESTRE

Others: Primer quadrimestre:
ORIOL ARTEAGA BARRIEL - 15
JUAN CAMPOS COLOMA - 14
CRINA MARIA COJOCARU - 11
OCTAVI LOPEZ CORONADO - 14
ANTONIO MARISCAL CASTILLA - 15
MARIA SAGRARIO MILLAN GARCIA VARELA - 12
MARIO MONTES USATEGUI - 15
ELISABET PEREZ CABRE - 12
JOSE FRANCISCO TRULL SILVESTRE - 11
ADAM VALLES MARI - 14

DEGREE COMPETENCES TO WHICH THE SUBJECT CONTRIBUTES

Specific:
CE5. Know how to perform and understand basic experiments that demonstrate the main phenomena of optics and photonics.
CE6. Have carried out a set of advanced laboratory works, similar to that of future experimental research work.

Generical:
CG2. Ability to modeling, calculate, simulate, develop and implement in research and technological centers and companies, particularly in research, development and innovation tasks in all areas related to Photonics.
CG3. Ability for technical direction and direction of research, development and innovation projects, in research centers, companies and technology centers, in the field of Photonics.

Transversal:
1. EFFECTIVE USE OF INFORMATION RESOURCES: Managing the acquisition, structuring, analysis and display of data and information in the chosen area of specialisation and critically assessing the results obtained.

2. ENTREPRENEURSHIP AND INNOVATION: Being aware of and understanding how companies are organised and the principles that govern their activity, and being able to understand employment regulations and the relationships between planning, industrial and commercial strategies, quality and profit.

3. FOREIGN LANGUAGE: Achieving a level of spoken and written proficiency in a foreign language, preferably English, that meets the needs of the profession and the labour market.

4. SUSTAINABILITY AND SOCIAL COMMITMENT: Being aware of and understanding the complexity of the economic and social phenomena typical of a welfare society, and being able to relate social welfare to globalisation and sustainability and to use technique, technology, economics and sustainability in a balanced and compatible manner.

5. TEAMWORK: Being able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available.

Basic:
CB7. Students should know how to apply the knowledge acquired and their problem-solving ability in new or little-known environments within broader (or multidisciplinary) contexts related to their area of ¿¿study.
CB6. Possess and understand knowledge that provides a basis or opportunity to be original in the development and/or application of ideas, often in a research context

TEACHING METHODOLOGY

- Laboratory sessions

LEARNING OBJECTIVES OF THE SUBJECT

"Photonics laboratory" aims to provide an experimental overview over different phenomena and aspects of PHOTONICS that are theoretically studied in the courses of this master. The course consists of 4 laboratory works of 8 hours each (2 sessions of 4 hours) and devoted to different topics of basic and applied photonics. We offer a list of 13 different laboratory works. Each student has to choose four laboratory works from this list, taking into account her/his preferences and availability of laboratories.
The guidelines for each subject (available in ATENEA), aims to provide an overview on each topic: a phenomenological study, description and interpretation of the phenomena that the student is supposed to observe in the lab, consolidation of basic theoretical concepts, manipulation of different experimental apparatus, definition of experimental objectives, etc. After the finalization of the work a written report has to be submitted.

STUDY LOAD

Type	Hours	Percentage
Hours small group	32,0	25.60
Self study	93,0	74.40

Total learning time: 125 h

CONTENTS

1. Polarization and polarizing materials

Description:
The aim of this laboratory session is to gain a deeper insight into the description and measurement of polarized light and its changes when the light beam is incident on different materials. The student will be introduced to the phenomenon of polarization by dichroism, obtaining polarized light by Brewster angle and Rayleigh scattering, birefringence, the nature of retarders and their use to obtain different states of polarization. Stokes formalism will be used to describe polarized light and Müeller matrices to describe the interaction with materials that modify the polarization state. The student will work with computer-controlled motorized retarder plates to calibrate a polarimeter, generate different polarization states, measure them, and obtain the Müeller array of optical devices.

Full-or-part-time: 8h
Laboratory classes: 8h

2. Light-matter interaction phenomena. The Zeeman Effect

Description:
Light-matter interaction phenomena deal essentially with the emission and absorption of light, and with the material medium influences on light propagation. The latter include reflection, refraction, diffraction, scattering, and light polarization phenomena. In the first lab session the student will deal with a variety of such phenomena at a phenomenological level by trying to observe and to interpret them. The second session is devoted to perform an experiment on the Zeeman Effect in Cadmium by characterizing the light emission features (frequency, polarization and direction of emission) and doing measurements leading to an evaluation of the Bohr's magnetron. Both normal and anomalous Zeeman effects are considered.

Full-or-part-time: 8h
Laboratory classes: 8h

3. Atomic spectroscopy. Optical pumping

Description:
The first session provides an overview of the classic spectroscopic techniques of light (prism, grating, Fabry-Perot) in relation to increasingly finer details of the atomic structure (line spectra, fine, hyperfine and Zeeman) and introduces a connection to the high-resolution techniques of spectroscopy with (rather than of) light. The second session consists of an optical pumping experiment in a vapor of 87Rb atoms with a diode laser, in which the angular momentum of light is used to pump atoms to atomic states that do not longer absorb light due to the angular momentum conservation law. The light creates strong population differences among the ground state sublevels and, at the same time, it provides high-sensitivity detection of any perturbation on such population differences: RF resonances, stray magnetic fields or collisions.

Full-or-part-time: 8h
Laboratory classes: 8h

4. Generation of diffractive optical elements with a liquid crystal spatial light modulator

Description:
In this laboratory the student will use a parallel aligned liquid crystal spatial light PALCSLM modulator working in phase mode to generate different diffractive optical elements DOE and computer-generated holograms CGH and produce the desired light distribution.
First the direction of the optical axis of the LC will be found to work in the phase regime. Optionally, if the student is very interested, the curve of the phase modulation versus the gray level will be measured.
Several methods will be use for the generation of the DOEs: 1.- Basic modifications of an analytical function, for instance, the phase produced by a lens. 2.- Techniques of CGHs by using several pixels to encode the desired complex modulation. 3.- Implementation of the Iterative Fourier Transform algorithm to consider the modulation restrictions in both spaces: Fourier and Spatial domain.
The student will have the opportunity to write the code in MATLAB to generate the image to be send to the SLM, and register the result with a CCD camera

Full-or-part-time: 8h
Laboratory classes: 8h

5. Optical trapping: understanding optical forces.

Description:
Optical trapping is an application of light that uses the momentum of photons to accelerate or trap at a fixed position in space small dielectric particles of micron size, including biological material such as small cells or cell's internal organelles. Optical traps or "tweezers" are able to generate forces in the range of pN, then comparable to the ones needed to deform a cell or stop swimming bacteria or sperm cells for example.
In this lab the student will get familiar with these concepts through a simulation software (firts 4h session) and end up using a real optical trapping setup with which they will capture small plastic beads and evaluate the optical forces applied on them (second 4h session).

Full-or-part-time: 8h
Laboratory classes: 8h

6. Optical trapping: building an optical trapping system from the ground up

Description:
This laboratory work starts with a small theoretical introduction to optical trapping physics where the basics of this technology will be explained. Then, the student will learn the different optical elements necessary to build an optical trapping setup from scratch, will learn how to assemble and align them into a functional setup and will finally use it to visualize and trap small dielectric particles (polystyrene, 3 μm) suspended in water.

Full-or-part-time: 8h
Laboratory classes: 8h

7. Study of the geometrical phase using geometrical phase lenses and polarization diffraction gratings

Description:
This laboratory work introduces the concept of geometrical phase trough a simple experimental set-up, using the possibilities offered by the new geometrical phase lenses and polarization diffraction gratings. In the first part students will made a qualitative study how a geometrical phase lent converge the right hand circular polarized light, while the left hand polarized light diverge. In the case of the polarization diffraction gratings the incident light is separated into their circular components. In the second part, students will study and undertake quantitative measurements of the geometrical phase implementing a Mueller microscope to observe, with micrometric resolution, different orientations of the optical axis on the surface of the lenses and diffraction gratings.

Full-or-part-time: 8h
Laboratory classes: 8h

8. Single-photon detection for fast-timing applications

Description:
In this laboratory the students will learn the basics of silicon photomultipliers (SiPMs), which are compact and fast photosensors sensitive to low-photon fluxes with a wide range of applications (e.g. high-energy physics, medical imaging, quantum communication, industrial applications...). Using pulsed lasers or LEDs they will mount a setup to visualize the discretization of the output pulses of SiPMs and they will be able to identify single photons. They will calibrate the SiPMs, study their time resolution and measure the detected photon fluxes.

Full-or-part-time: 8h
Laboratory classes: 8h

9. Active and nonlinear optical media: building a Nd:YAG laser and harmonic generation

Description:
This laboratory work gives the opportunity to build up a versatile set-up for the experimental study of the laser operation. The student can study different aspects of individual elements of the laser assembly. The work is organized in four main experiments, closely related between them: (1) study of the behavior and characteristics of a tunable diode laser; (2) the tunable wavelength of the diode is exploited to measure the absorption spectrum of a Nd:YAG crystal; (3) set-up, alignment and study of a Nd:YAG laser in continuous and pulsed emission regimes; (4) study of the intracavity nonlinear second harmonic generation.

Full-or-part-time: 8h
Laboratory classes: 8h

10. Photoemitters and photodetectors.

Description:
The first part of this laboratory work is focused to the experimental study of the main characteristics of different types of photo emitters, generally used in photonics: thermal and halogen lamps, discharge and fluorescent lamps, LEDs and lasers. An overview over the theoretical basis of these devices is given in the core course "Introduction to Photonics". In the second part we will study the response of several photo detectors (sensitivity and spectral response, temporal response, modulation, linearity, etc). This experience will evidence the physical characteristics of these devices and helps the student to gain practice in their use. Finally, the student will operate several photonic devices that combine photoemitters and photodetectors and their applications for distance measurements: laser range finder, sensitive thickness measurements, laser distance meter.

Full-or-part-time: 8h
Laboratory classes: 8h

11. Optical image processing

Description:
This lab experiment is strongly recommended for students following the Beam Propagation and Fourier Optics course of the Master and those seeking experimental background on Fourier analysis. Students have the opportunity to handle an optical set-up to obtain optical Fourier transforms. Properties of the FT as well as different setup configurations are analyzed in-situ. Interpretation of periodic and non-periodic objects is carried out by Fourier plane analysis. Direct grating frequency measurement is also performed. The second part of the lab session is focused on two different experiments: Firstly, the optical demonstration of the convolution theorem and secondly, image filtering and retrieving. Students analyze the effects of filtering out some selected frequencies on the retrieval of complex objects.

Full-or-part-time: 8h
Laboratory classes: 8h

12. Hands on image sensors

Description:
The possibility of handling different image sensors is offered in this lab experiment. From CCD area arrays to linear arrays; from monochrome to color cameras and NIR cameras; from high spatial resolution to high dynamic range and high velocity image capturing sensors. All these image sensors are broadly used in vision applications, where image acquisition is a crucial step for appropriate image analysis and interpretation. Students evaluate and compare common camera features such as its spectral response, its responsivity, and its dynamic range. The importance of the illumination and the imaging optics are pointed out in the experimental session. The optical quality of the imaging system is analyzed in terms of its modulation transfer function (MTF) and possible noise sources are identified.

Full-or-part-time: 8h
Laboratory classes: 8h

13. Optical fibers: hands-on and characterization

Description:
This laboratory work provides to the student the opportunity to have a first experience on handling optical fibers for telecommunications. The objectives of this laboratory work are that, after the realization of this practice, the students will be able to: perform a fusion splice between two fibers for a durable and stable connection between the fibers; assemble an optical connector for temporal connection; characterize the basic parameters of the optical fibers for telecommunication as they are measure the core diameter of the fiber, measure the numerical aperture of the fiber; checking by experimental measurement of the specifications of optical couplers as e.g.: the optical coupler splitting ratio and the return losses.

Full-or-part-time: 8h
Laboratory classes: 8h

14. Optical fiber transmission

Description:
The first part of this laboratory work provides to the student with the necessary skills and experience for auditing optical fiber links, by learning and training using a Time Domain Reflectometer, thus analyzing the length, quality and possible fiber faults. The second part of this laboratory work provides to the student with the skills and experience for testing a basic optical fiber system and its devices like optical transmitters (LED and LASER) and receivers (PIN), by characterizing the optical spectrum of both main optical transmitters, their linearity, bandwidth and temperature performance dependence.

Full-or-part-time: 8h
Laboratory classes: 8h

GRADING SYSTEM

- Reports corresponding to the laboratory works done by the student. (70%).
The reports should be delivered in two weeks after the laboratory session.
- Evaluation of individual student activity in the laboratory and previous preparation of the guidelines (30%).