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230551 - LAB - Photonics Laboratory

Coordinating unit: 230 - ETSETB - Barcelona School of Telecommunications Engineering
Teaching unit: 748 - FIS - Department of Physics
Academic year: 2017
Degree: MASTER'S DEGREE IN PHOTONICS (Syllabus 2013). (Teaching unit Compulsory)
ECTS credits: 5 Teaching languages: English

Teaching staff

Coordinator: C. Cojocaru (UPC)

Others: Santiago Vallmitjana (UB)
Ignasi Juvells (UB)
Irene Estévez (UAB)
Jordi Mompart (UAB)
Francesc Pi (UAB)
Gaspar Orriols (UAB)
Josep Prat (UPC)
José A. Lázaro (UPC)
Elisabet Perez (UPC)
José Trull (UPC)

Degree competences to which the subject contributes

Basic:

CB7. (ENG) Que los estudiantes sepan aplicar los conocimientos adquiridos y su capacidad de resolución de problemas en entornos nuevos o poco conocidos dentro de contextos más amplios (o multidisciplinares) relacionados con su área de estudio.

CB6. (ENG) Poseer y comprender conocimientos que aporten una base u oportunidad de ser originales en el desarrollo y/o aplicación de ideas, a menudo en un contexto de investigación

Specific:

CE5. (ENG) Màster en Fotònica:
Saber realizar y comprender experimentos básicos que demuestren los principales fenómenos de óptica y fotónica.

CE6. (ENG) Màster en Fotònica:
Haber realizado un conjunto de prácticas de laboratorio de nivel avanzado, similar al de futuros trabajos experimentales de investigación

Generical:

CG2. (ENG) Màster en Fotònica:
Capacidad para la modelización, cálculo, simulación, desarrollo e implantación en centros de investigación, centros tecnológicos y empresas, particularmente en tareas de investigación, desarrollo e innovación en todos los ámbitos relacionados con la Fotónica.

CG3. (ENG) Màster en Fotònica:
Capacidad para la dirección técnica y dirección de proyectos de investigación, desarrollo e innovación, en centros de investigación, empresas y centros tecnológicos, en el ámbito de la Fotónica

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.

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

Total learning time: 125h	Hours small group:	41h 15m	33.00%
	Self study:	83h 45m	67.00%

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Content

1. Interference in amplitude division devices. Nonlinear effects in a Michelson interferometer	Learning time: 8h Theory classes: 8h

Description:
The first session offers an overview of the amplitude division interferometers by analyzing their variety of configurations and with emphasis on the Michelson and Fabry-Perot devices. In the second session, the relative behavior of the two outputs of a Michelson interferometer is characterized according to the kind of beam splitter employed and, in the case of an absorbing divider yielding in-phase behavior of the two outputs, nonlinear effects like switching jumps and hysteresis are observed and analyzed. The experiment is an introduction to optical bistability.

2. Polarization and polarizing materials	Learning time: 8h Theory classes: 8h

Description:
The aim of this laboratory work is to get a deeper insight in the description and measure of polarized light, and its change when the light beam impinges on different materials. Stokes formalism will be used to describe fully polarized light and partially polarized light. The interaction with the material will be described with the Mueller matrices. The student will work with rotating wave-plates Stokes/Mueller polarimeters. The wave-plates are motorized and the device is controlled by a LabView program that could be modified by the student, or be used as it is. First the calibration of the polarimeter will be performed. Next the student will generate different polarization states and measure them. Finally, the Mueller matrix of different optical devices will be measured: Wave-plates, scotch, plastics, and a liquid crystal cell.

3. Light-matter interaction phenomena. The Zeeman Effect	Learning time: 8h Theory classes: 8h

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.

4. Atomic spectroscopy. Optical pumping	Learning time: 8h Theory classes: 8h

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.

5. Mutual Intensity. Measurement of degree of spatial coherence	Learning time: 8h Theory classes: 8h

Description:
The aim of this laboratory work is to analyze different aspects of the phenomena of Young interference and establish its relationship with the coherence of light. In the first session, using simulation tools, a general review of experimental techniques to perform interference will be carried out and an experimental setup will be assembled depending on the knowledge of the student. The second session will be an experiment to quantify the spatial coherence of a light source from the measurement of visibility of Young's interference fringes by means of a partially coherent extended source. The idea is performs a high-precision automated quantitative recreation of the Thomson and Wolf experiment using a CCD camera and a spatially incoherent source generated from a laser beam.

6. Fractional Talbot images generation by Fresnel diffraction	Learning time: 8h Theory classes: 8h

Description:
The purpose of this laboratory is to examine different aspects of the Fresnel diffraction of periodic objects. In the first session, after the use of simulation programs to analyze Fresnel and Fraunhofer diffraction of different objects, experimental setups will be assembled in order to see the different types of diffraction and the influence of the parameters involved in the process. Both the simulation and experiments will be tailored to the knowledge and previous experience of the students. The second session will deal with a particular case of Fresnel diffraction: the Talbot effect. This effect allows the formation of self-images of regular objects without lenses. If we study the distribution of light in different planes, a fractional Talbot images are obtained. An experimental setup will be assembled and the conditions of image formation and their characteristics will be measured.

7. Dealing with resolution and magnification: telescopes and microscopes	Learning time: 8h Theory classes: 8h

Description:
The experiments of this laboratory work deal with the resolution limits imposed by the presence of aberrations and diffraction in both telescopes and microscopes. In the first part a ray- tracing program allows us to design projects of telescopes and microscopes, which will be actually tested in an optical bench. The telescopes are tested by means of resolution charts and comparing corrected and non-corrected objectives. In the second part the resolving power is measured by using resolution tests in a classical and in an inverted microscope. The correlation between resolution and numerical aperture becomes evident. Other features such as recording through a CCD camera and specimen measuring methods are also experimentally studied. Techniques for improving the visibility and the technique of phase contrast are also well experimented

8. Active and nonlinear optical media: lasers and harmonic generation	Learning time: 8h Theory classes: 8h

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.

9. Photoemitters and photodetectors. Distance measurements with laser	Learning time: 8h Theory classes: 8h

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.

10. Optical image processing	Learning time: 8h Theory classes: 8h

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.

11. Hands on image sensors	Learning time: 8h Theory classes: 8h

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.

12. Optical fibers: hands-on and characterization	Learning time: 8h Theory classes: 8h

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: (1) fabricate an optical connector for temporal connection between to fibers; (2) do a fusion splice between two fibers for a durable and more stable connection between the fibers; (3) characterize the basic parameters of the optical fibers for telecommunication as they are (3-a) measure the core diameter of the fiber, (3-b) measure the numerical aperture of the fiber; (4) checking by experimental measurement of the specifications of optical couplers as e.g.: the optical coupler splitting ratio and t he return losses.

13. Optical fiber transmission: network and devices	Learning time: 8h Theory classes: 8h

Description:
The first part of this laboratory work provides to the student with the necessary skills and experience for auditing Optical Fiber Links and Networks, by learning and training using a Time Domain Reflectometer, thus analyzing the length, quality and possible fiber faults in Optical Fiber Links and Networks. The second part of this laboratory work provides to the student with the skills and experience for testing a basic Optical Fiber System devices as the most basic optical transmitters (LED) and receivers (PIN), and also extended to higher efficiency optical transmitters (Semiconductor-LASER), by characterizing the optical spectrum of both main optical transmitters (LED and LASER), their linearity and temperature performance dependence.

14. Optical fiber communication systems (Erbium Doped Fiber Amplifiers)	Learning time: 8h Theory classes: 8h

Description:
This laboratory work provides to the student, on the one hand, a first experimental contact with optical amplifiers based in Erbium Doped Fibers, both showing the physical properties of the Erbium Doped Fiber Amplifier (EDFA) deriving from the transitions of the Erbium ions among their quantized energy states, and also showing how those EDFA physical properties affect to the performance in WDM Optical Fiber Systems, where the EDFA is used for all-optical, transparent regeneration. On the other hand, this laboratory work extends the characterization of Optical Fiber Systems analyzing the transmission/reception bandwidth of: transmitter, receiver, fiber, and the whole transmission capacity of the integrated Optical Fiber System, using a Network Analyzer.

Qualification 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%).

Bibliography