Master's Degree in Photonic Engineering

Curriculum Overview

The structure of the master is shown in the following figure, it is a master's degree that is taught during an academic course with a set of 30 ECTS (European Credits Transfer) of compulsory subjects, 18 ECTS of elective subjects and 12 ECTS of Master's thesis Work.

The optional subjects are distributed in 2 training tracks. The student should choose at least 12 ECTS within a specific track to get a mention on it. It is also possible to combine subjects from both tracks. Plus a *New Trends and Entrepreneurship* subject is offered, which includes a series of seminars, including activities related to entrepreneurship (how to start a spin-off, intellectual property rights, Innovation management ...), along with an optional internship for the development of photonic systems applications. This subject allows to approach the student to practical cases in the professional environment or to the latest research trends. There is also the possibility of developing short international mobility activities.

The following table presents the different modulus of the master's degree.

M1	Advanced fundamentals in photonic engineering (18 ECTS)
M2	Lab and tools (9 ECTS)
M3	Photonic systems (I1) (18 ECTS)
M4	Photonic devices (I2) (18 ECTS)
M5	New Trends and Entrepreneurship (9 ECTS)
M6	Master thesis (12 ECTS)

In the compulsory subjects, the basic fundamentals for the design of photonic subsystems with novel technologies are covered, from an applied engineering perspective (in modulus M1) and its practical implementation at the laboratory level together with the necessary simulation tools (in modulus M2). Most of the elective credits are distributed in 2 tracks: photonic systems (I1) described in modulus M3 and photonics devices (I2) described in modulus M4. There is another modulus M5 including internship, and compulsory entrepreneur activities.
The different subjects will be taught at one of the 3 universities that participate in the master degree program: Carlos III of Madrid University, Polytechnic of Madrid University and Alcalá University.

Structure of the curriculum by modules and subjects

	MODULE	SUBJECT	ECTS	Type
APPLIED PHOTONICS	M1.ADVANCED PHOTONICS ENGINEERING BASICS	Photonics Technologies I	6	C
		Photonics Technologies II	6	C
		Photonics Technologies III	6	C
		TOTAL ECTS SUBJECT	18	
	M2.LAB and TOOLS	Lab project I	3	C
		Lab project II	3	E
		Simulation tools / Simulation tools	3	C
		TOTAL ECTS SUBJECT	9	
TRACKS	M3. PHOTONIC SYSTEMS	Electives subjects on track 1 (I1)	18	E
		TOTAL ECTS	18	
	M4. PHOTONIC DEVICES	Electives subjects on track 2 *(I2)*	18	E
		TOTAL ECTS	18	
NEW TRENDS AND ENTREPRENEURSHIP	M5. NEW TRENDS AND ENTREPRENEURSHIP	Seminars and workshops	6	C
		Internship	3	E
		TOTAL ECTS	9	
MASTER THESIS	M6. MASTER THESIS	Master thesis	12	TFM
		TOTAL ECTS	12	

C=Compulsory; E=Elective

Module 1	
Denomination: Advanced Fundamentals of Photonics Engineering	
ECTS	**Subject character (compulsory or elective or mixed or Master Thesis)**
18	Compulsory
Duration and semester	
The module comprises 3 compulsory subjects of 6 ECTS (European Credit Transfers) taught in the first semester.	
Learning outcomes	
Students should be able to do the following upon completion of this module: • To analyze optic and photonic systems in free space and guided media • To understand the bases of operation of passive optical elements (lenses, diffraction gratings, polarizers, optical fibers, etc.) and select and use the most appropriate ones in an application. • To apply knowledge of electromagnetic optics to the propagation of signals in optical fibers. • To analyze and apply quantum electronics knowledge for selecting and using lasers, amplifiers and other optical sources in photonic systems. • To understand the basis of operation of devices based on electro-, magneto-, acousto-optic	

effect to select and to use the most suitable in an application.
- To specify and design photonic systems based on discrete components for sensor applications.
- To understand and apply optical modulation and multiplexing techniques.
- To understand the basics of photodetectors, photoelectric matrices, amplifiers and signal conditioning to select and use the most suitable ones in an application.
- To know the noise sources in photonic systems in order to evaluate their performance.
- To apply signal and image processing techniques to improve optical systems.
- To analyze current optical communications systems.

Subjects

Subject	ECTS	Type	Character
Photonic Technologies I	6	1st semester	C
Photonic Technologies II	6	1st semester	C
Photonic Technologies III	6	1st semester	C

Contents description

Photonic Technologies I

Theory of diffraction and image formation. Propagation of Gaussian beams. Propagation in dispersive and anisotropic media. Devices based on polarization. Devices based on periodic structures. Optical waveguides. Fiber optics: types and propagation of light.

Photonic Technologies II

Fundamentals of laser amplification. Nonlinear optical effects. Optical fiber amplifiers. Emission characteristics of continuous and pulsed lasers. Optical semiconductor sources. Electro-optical devices. Space modulators of light. Acoustic and Magneto-optical devices.

Photonic Technologies III

Modulation and multiplexing of optical signals. Photonic sensors. Photodetectors. Noise in photodetectors. Detector matrices. Amplification and conditioning of signal. Acquisition and processing of signal and image. Fiber optic communications.

Observations

This subject provides the students the fundamental knowledge for the correct development of the different tracks proposed in the Master. In this sense, the proposed contents provide new tools and concepts associated with the operation, specification and design of photonic systems including the selection and use of active and passive photonic devices available in the market and incorporated in photonic systems with high added value.

MODULE 2	
Laboratory and Tools	
ECTS	**Subject character (Compulsory/ elective/ mixed/ Master thesis)**
9	Mixed

Duration and Semester

The module comprises two compulsory and one elective subjects of 3 ECTS.

Learning outcomes

Students should be able to do the following upon completion of this module:

- To apply the most commonly used simulation tools in photonics applications.
- To use laboratory test equipment useful in photonics applications.
- To design and develop full opto-electronic systems by using the photonics-related components and technologies studied along the master.
- To design and develop the required test and measurements procedures to evaluate the working operation of an optoelectronic system.
- To apply the knowledge within the photonic engineering field in a real-life environment both at component and at system level.
- To work effectively in a multidisciplinary group in the photonic engineering field with the ability to react to technical and operative difficulties in a technological project.
- To support properly a developed project defending it against third parties.

Subjects

Subject	Credit	Type	Character
Simulation tolos	3	Annual	C
Lab project I	3	Annual	C
Lab projects II	3	Annual	E

Contents description

Photonic simulation tools, the student will chose among different photonic simulation tools useful for the design of the photonics systems to be implemented in the lab. The offer of simulation tools comprises tools for simulating photonics integrate circuits, systems based on ray-optics, optical networks, photonic components as well as to control lab instrumentation.

There will be an offer of at least 5 simulation tools of 1 ECTS each, the student will choose 3 out of 5 offered. The students will work individually or in groups to familiarize with each tool.

The subjects **Lab Project I** and **Lab Project II** allow the student to develop a laboratory project from a list of proposals. Each project will comprise a complete system of moderate complexity covering a specific photonic application, for example, an instrumentation system based on fiber Bragg gratings for the quasi-distributed temperature measurement in a tunnel. The compulsory and elective subjects offered during the first semester will be taken into account to conform the list of projects, trying to cover several application areas related to the field of photonic engineering.
The student will participate within a team in the assigned project and must coordinate with the rest of the members of the team to develop the project. Both the team performance and individual performance will be assessed.
Two types of projects will be offered, ones of short duration and a smaller complexity and some of long duration and higher complexity.

Lab. Project I. The projects will give a set of specifications and minimum performance requirements. In the case of long-term projects, development will be divided in two phases with separate specifications and requirements. As the subject is compulsory, all students must develop and evaluate experimentally at least one project of short duration, or the first phase of a long-term project.

Lab. Project II. Students who choose this subject should develop a long-term project. The course covers the second phase of the project. If the assignment of such a project is not possible, a second project of short duration will be assigned.

Observations

This is a practical module where the student is encouraged to work as a part of a team. In this module, the student will study the design, development, implementation and evaluation of a photonic system in a given application. This work requires knowledge and managing of design and simulation tools, development tools, and techniques and measurement equipment.
This module helps to acquire specific skills related to the management of design simulation tools, and with the identification of the application of photonics technology in complex systems, the required photonic subsystem and performance as well as its integration and validation within the whole system. The specific skill concerning the managing of lab equipment specific of photonic technology is also addressed.
The module enforce the acquisition of important general skills like to work effectively in a group with a multidisciplinary point of view managing a project evolution, to elaborate clear and well-supported working plans and projects and the related documents in English language in the field of photonic engineering. The module also helps the acquisition of skill related to the use the scientific method as a fundamental work tool to apply both in the professional and research fields, managing the sources of information.
The assessment procedure comprises the evaluation of the achieving of partial goals throughout the project development, and a final test that includes a small project memory. The former will have a greater weight in the final mark to encourage the students to achieve successfully the partial objectives of the project.
In the case of the simulation tools, the student will also have to present a report with the simulations carried out and pass a final assessment concerning the handling of the tools.

Module 3	
Denomination: Photonic Systems-I1	
ECTS	**Subject character (compulsory / elective / mixed / Master Thesis / etc work.)**
18	Elective

Duration and semester

The module comprises six elective subjects of 3 ECTS.

Learning outcomes

Students should be able to do the following upon completion of this module:

• From a capture of specifications, be able to identify the different parts necessary for obtaining the desired functionality (information transmission, optical propagation medium, receiver, information retrieval) and perform the specification of the different subsystems.

• To analyze, understand and solve a complex photonic problem from the origin to the end, from aspects such as conceptual planning, bibliographic search to oral and / or written communication of results, in accordance with scientific procedures and methods.

• To know the main concepts and tools needed to understand the different optical phenomena of application in sectors such as biomedicine, industry, communications, image, etc.

• From the specifications and requirements of the different blocks that make up a photonic system focused on a specific professional application or research activity, know the tools necessary for the development of the blocks, and plan such development and integration of all the blocks.

• To design, implement and characterize photonic systems from their components for applications in different productive sectors.

Subjects

Subject	ECTS	Type	Character
Optical Communications Systems	3	Annual	E
Distributed Fiber Optic Sensing sensors	3	Annual	E
Optical sensors sensor networks	3	Annual	E
Assistive Photonics	3	Annual	E
Lidar system and applications	3	Annual	E
Imaging Systems	3	Annual	E

Contents description
The subject has a set of elective subjects that cover different aspects and blocks of the photonic systems of application in different fields: telecommunications, biomedical, industrial, among others. The following is an example of the subjects that would be offered at the beginning of the implementation of the teachings and their contents, which may be substituted by other equivalents depending on the future developments of the photonic systems: **Optical communications systems:** Elements of an optical link; Features of an optical link; Systems with wavelength multiplexing; Coherent systems. **Distributed fiber optic sensors:** nonlinear effects in optical fiber for sensing, sensors based on scattering stimulated Brillouin and Raman, sensors based on coherent reflectometry. **Optical sensor networks:** features and remote power supply. Temporal, spatial multiplexing, WDM techniques and integration of self-reference techniques for current sensors, quasi-distributed sensor networks. **Assistive Photonics:** application of the Design for All (DpT) guidelines in photonic systems, augmented reality and virtual reality as tools for rehabilitation, display technologies to improve accessibility. **Lidar system and applications:** Continuous and pulsed systems; Distance and sweep measurement in 2D and 3D; Measurement of atmospheric parameters **Imaging systems:** resolution and linearity in CCD and CMOS image systems; Adaptive optics; stereoscopy. It should be noted that given the speed with which vary the different disciplines and technologies involved in the aforementioned photonic systems, this subject will be dynamic and the set of subjects that are offered will not always be the same and can be modified according to new advances and methods that continuously are emerging, disruptive technologies, etc. So that they could be incorporated as new elective subjects to offer within this module upon consideration of the Academic Commission of the Master.
Observations
The subjects contained in this block are elective and it is expected that the students have successfully completed the blocks of related compulsory subjects. Upon advice of the tutor and according to the interests of the student, the elective subjects will be selected and the student will be reminded of the need already mentioned to take advantage of the contents of the compulsory subjects. The student, who completes a minimum number of 12 ECTS of this subject, will have completed the track of Photonic Systems-I1 that gives him the ability to conceive a complete photonic system from a capture of specifications. As a result, upon completing the track, it will be able to design, specify and supervise the manufacture of prototypes and final products based on high value-added components and photonic subsystems, either in the professional field or in the framework of R + D + I.

Module 4	
Photonic Devices	
ECTS	**Subject character (Compulsory/ elective/ mixed/ Master thesis)**
18	Elective

Duration and Semester

The module comprises six elective subjects of 3 ETCS.

Learning outcomes

Students should be able to do the following upon completion of this module:

- To apply the appropriate analysis tools to determine the performance of photonics devices as a part of complex systems.
- To design photonics devices and circuits for specific functionalities in a given application, determining the required photonics components and the possibility of their integration in a complex circuit.
- To describe the structure, technology, application fields and limitations of organic photonics devices for emission and detection, as well as to design and characterize liquid crystal structures for photonic processing applications.
- To describe the fundamentals of the interaction of light and biomaterials and its applications to sensing in biomedicine, choosing the required radiation and sensing technique to cope with a specified biomedical application.
- To describe the development techniques and applications of advanced lasers and their limitations and differences between commercial lasers, choosing the most suitable type of laser for a specific application.
- To define and apply the design rules of complex semiconductor-based laser structures required to obtain devices with unique performance, showing their potential applications.
- To define and apply the nanophotonics fundamental concepts to design, fabricate and characterize photonic nano-devices to manage and detecting light in a given application field.

Subjects

Subject	Credit	Type	Character
Photonics Integrated Circuits	3	Annual	E
Organic photonics	3	Annual	E
Biophotonics	3	Annual	E
Ultrafast photonics	3	Annual	E
Advanced Semiconductor lasers	3	Annual	E
Nanophotonics	3	Annual	E

Contents description

The module comprises a set of elective subjects covering different aspects and types of photonic devices and their applications in areas such as telecommunications, biophotonics and nanophotonics. This module is intended to cover a wide range of technologies to deliver the required background about the current state of photonic devices and technologies to facilitate the selection of the most suitable for a given application as well as the development of innovative devices to increase the range of applications.
The following is an example of the subjects and contents that would be offered at the beginning of the implementation of the Master. These subjects may be replaced by other equivalents depending on the future developments of the photonic devices:

Photonics Integrated Circuits: Concepts and tools necessary to understand the operation and design the components of a photonic integrated circuits, such as ring or multimode interference (MMI) Mach-Zehnder interferometers, as well as their integration into complex circuits. Technologies and materials used for the fabrication of photonic integrated circuits.

Organic photonics: Devices based on liquid crystals. Organic Light emitting diodes (LED)s. Organic detectors. Presentation screens.

Biophotonics: Interaction of light and biomaterials. Ligth sources and ranges of emission wavelength of interest for biomedical sensing. Detection and image techniques used in biomedicine.

Ultrafast photonics: Ultrafast lasers types, mode-locked lasers and development techniques. Nonlinear optical properties of photonics materials for generating ultrashort pulses. Soliton emission. Applications of ultrafast lasers in optical communications, spectroscopy and sensing.

Advanced Semiconductor lasers: Laser diodes with narrow linewidth; Tuneable laser diodes; High-power laser diodes.

Nanophotonics: Fundamentals and applications of nanophotonics, near - field theory and radiation-matter interaction below the diffraction limit. Properties and operating principles of nanophotonic devices.

It should be noted that due to the fast evolution of the different disciplines and technologies involved in the aforementioned photonic systems, this module will be adaptive and the offered set of subjects could be modified according to the emerging of new developments and methods. The new optional subjects could be incorporated to offer within this module after the approval by the Academic Commission of the Master.

Observations

All the subjects of this module are elective and they require a knowledge background that the student should reach when completing successfully the related compulsory subjects. The tutor will guide the student in the choice of electives and the student will be reminded of the need to take advantage of the contents of the compulsory subjects.
Students who complete a minimum of 12 ECTS of this module will have completed the itinerary of

"photonic devices".
The module covers the study of novel devices and their applications, many of them still being optimized by research laboratories. Following this research point of view, the module contributes to the acquisition of competencies related to knowledge comprehension that allows to do original proposals and of application of acquired knowledge and problem resolution.
The module also helps to acquire the competencies to propose, design and implement a system with photonic components and it enhances understanding by students of novel photonic technologies such as biophotonics, nanophotonics and photonic integrated circuits, and its use and integration for the resolution of new problems and applications.
Finally the module also helps to acquire specific skills like management design tools, on current trends in photonic applications, on the selection and design of novel photonic components, technologies and subsystems and the effective search of information and identification of the state of the art in a technological problem involving photonic devices.

Module 5	
New trends and entrepreneurship	
Number of credits ECTS	**Subject character (Compulsory/ elective/ mixed/ Master thesis)**
9	Mixed
Ng duration and temporal location within the curriculum	
The module comprises 6 ECTS in compulsory seminars and 3 ECTS in elective subjects of 3 ETCS	
Learning outcomes that the student acquires	
After completion, students should be able to identify from a conceptual and practical point of view the main scientific and technological challenges in different photonics applications, as well as their integration and use. The set of seminars will be change dynamically according to the current state of the art, as they are oriented to the presentation of the cutting-edge topics, both professionally and in researching. Students are expected to be aware of the sectors with the greatest impact and to acquire the knowledge of the practical problems that can be found in the development of a photonic system in the business environment. Also it is expected they can identify the technologies and systems with higher innovative or research potential in various fields. The interaction with excellent researchers at international level or good professionals will be provided. It is expected that students learn about the different stages to take an idea from lab to market and to meet the essential aspects that defines novelty and inventive step in a patent, among others.	

Subjects

Subject	Credits	Cuatrim	Character	Language
Seminars	6	ANNUAL	C	English

Internship	3	ANNUAL	E	English

Content description

The seminars will be oriented either to professional or researching scope. In the seminars of professional character market perspective and real study cases, standards, and certification related to systems with photonic components will be covered.
As for the seminars related to entrepreneurship, will be eminently practical They will cover among others: experience in starting spin-off, patents and industrial property rights, innovation management, ...
Among the elective credits, students can do an internship in a company to get professional experience in the sector.

M 6

Master's Thesis (TFM)

Number of credits ECTS	Subject character (Compulsory/ elective/ mixed/ Master thesis)
12	Master's Thesis (Compulsory)

TFM can be done within the university or in a company or abroad in those institutions where an agreement has been settle down.

Learning outcomes acquired by the student

Master's Thesis (TFM) will consist of the realization of a comprehensive project or work of original research in the field of Photonics Engineering. This is an individual work that will be defended in public in front of a technical jury. TFM summarizes the skills acquired by the student upon completion of the master program.

Subjects

Subject	Cr edits	Cuatrim	CharaCTER	Language
Master thesis	12	ANNUAL	C	English

Brief description of contents

The student will develop the TFM led by a teacher who will guide him/her in defining the initial objectives, in the planning of work and development. It shall review ITS documentation and oral presentation proposal.

Observations

Before Master's Thesis defense students should have passed the 30 ECTS credits of compulsory courses and 18 credits of electives courses.
The following criteria will be use to evaluate the student work

	CRITERIA
MEMORY	Organization / Structure and conciseness (Summary)
	Document presentation

	Problem / state of the art and specific information search in the field effectively treated
	Design alternatives and effective techniques in the selection Compared of the solution, Identifying new environments, new technologies and major challenges
	Planning and multidisciplinary approach
	Implementation and judgment about the issue addressed
DEFENSE	Outline and presentation
	Oral presentation: communication skills and specific technical issues related to the master
	Work discussion
CONTRIBUTION / STUDENT EFFORT	Contribution / Contribution technically, Including the Ability of autonomous learning, the originality of the solution provided and the scientific method used
	Objectives achievement
	Personal work (Tutor Report)