Nanoelectronics and Nanophotonics

Academic Year: (2024 / 2025) **Review date: 16-04-2024**

Department assigned to the subject: Electronic Technology Department

Coordinating teacher: GARCIA CAMARA, BRAULIO

Type: Compulsory ECTS Credits : 6.0

Year : 4 Semester : 1

REQUIREMENTS (SUBJECTS THAT ARE ASSUMED TO BE KNOWN)

It is recommended to have attended and passed the subjects of Advanced Quantum Physics, Electromagnetic Fields and Waves, Fundamentals of Electronic and Photonic Engineering

SKILLS AND LEARNING OUTCOMES

CB1. Students have demonstrated possession and understanding of knowledge in an area of study that builds on the foundation of general secondary education, and is usually at a level that, while relying on advanced textbooks, also includes some aspects that involve knowledge from the cutting edge of their field of study.
CB2. Students are able to apply their knowledge to their work or vocation in a professional manner and possess the competences usually demonstrated through the development and defence of arguments and problem solving within their field of study.
CB3. Students have the ability to gather and interpret relevant data (usually within their field of study) in order to make judgements which include reflection on relevant social, scientific or ethical issues.
CB4. Students should be able to communicate information, ideas, problems and solutions to both specialist and non-specialist audiences.
CB5. Students will have developed the learning skills necessary to undertake further study with a high degree of autonomy.
CG2. Learn new methods and technologies from basic scientific and technical knowledge, and being able to adapt to new situations.
CG3. Solve problems with initiative, decision making, creativity, and communicate and transmit knowledge, skills and abilities, understanding the ethical, social and professional responsibility of the engineering activity. Capacity for leadership, innovation and entrepreneurial spirit.
CG4. Solve mathematical, physical, chemical, biological and technological problems that may arise within the framework of the applications of quantum technologies, nanotechnology, biology, micro- and nano-electronics and photonics in various fields of engineering.
CG5. Use the theoretical and practical knowledge acquired in the definition, approach and resolution of problems in the framework of the exercise of their profession.
CG6. Develop new products and services based on the use and exploitation of new technologies related to physical engineering.
CG7. Undertake further specialized studies, both in physics and in the various branches of engineering.
CE13. Understand and handle solid state physical principles relevant to engineering and, in particular, semiconductors for application in electronic and photonic components, as well as the fundamentals and applications of analog and digital electronics and microprocessors.
CE14. Specify and use electronic instrumentation, measurement systems, sensors, techniques and experimental procedures usual and advanced in physics, engineering and biology, including electromechanical and microfluidic microdevices, and design experiments using the scientific method.
CE15. Understand and handle the physical principles associated with light-matter interaction and to apply them to the use and design of various photonic devices and complete photonic systems, as well as to apply photonic devices and systems in different branches of physics, engineering and biology.
CE19. Understand and handle the concepts of nanoelectronic and nanophotonic devices, the physical principles that govern them, their behavior and their applications for solving problems typical of the various branches of engineering including bioengineering.
CT1. Work in multidisciplinary and international teams as well as organize and plan work making the right decisions based on available information, gathering and interpreting relevant data to make judgments and critical thinking within the area of study.

RA1. To have acquired sufficient knowledge and proved a sufficiently deep comprehension of the basic principles, both theoretical and practical, and methodology of the more important fields in science and technology as to be able to work successfully in them.
RA2. To be able, using arguments, strategies and procedures developed by themselves, to apply their knowledge and abilities to the successful solution of complex technological problems that require creating and innovative thinking.
RA3. To be able to search for, collect and interpret relevant information and data to back up their conclusions including, whenever needed, the consideration of any social, scientific and ethical aspects relevant in their field of study.
RA4. To be able to successfully manage themselves in the complex situations that might arise in their academic or professional fields of study and that might require the development of novel approaches or solutions.
RA6. To be aware of their own shortcomings and formative needs in their field of specialty, and to be able to plan and organize their own training with a high degree of independence.

OBJECTIVES

The objective of this subject is that the student acquires the basic knowledge in the latest advances and the evolution of Nanotechnology with special emphasis on the fields of electronics and photonics. To achieve this goal, it is intended that the student acquires the following knowledge:

1.- A knowledge of the physical principles and basic operation of the main electronic nanodevices
2.- A knowledge of the physical principles of light control at the nanoscale and the operation of some of the current photonic nanodevices.
3.- To understand the main techniques of manufacturing devices in the micro and nano-scale.
4.- To understand the applications in the fields of Nanoelectronics and Nanophotonics.
5.- An ability to analyze the latest advances and challenges in these fields of knowledge.

As for the skills, in this subject the following will be developed:

- Ability to apply and disseminate the knowledge acquired in electronic and photonic nanodevices, as well as the scientific methodology associated with each of the fields.
- Ability to solve problems associated with each thematic block of the subject.
- Ability to consult and analyze the state of the art and technology in nanotechnology.
- Ability to use simulation tools for the design and characterization of electronic and photonic nanodevices.

DESCRIPTION OF CONTENTS: PROGRAMME

CONTENTS OF THE SUBJECT

1.- Review of some fundamental concepts.

1.1 Electron and photon as quantum particles: similarities and differences.
1.2 Uncertainty principle: practical implications
1.3 Top-down and bottom-up approaches to nanoelectronics and nanophotonics.

2.- Nanoelectronics.

2.1 Free electrons, confined electrons and electrons in periodic potential fields. Tunnel Junctions and applications.
2.2 Coulomb Blockade and the single-electron transistor.
2.3 Semiconductor quantum wells, quantum wires and quantum dots.
2.4 Nanowires, ballistic transport and Spin transport.
2.5 Examples of nanolectronic devices and applications

3.- Nanophotonics

3.1 Far-field, near-field, diffraction limit and evanescence waves.
3.2 Mie Theory.
3.3 Plasmonics and dielectric resonant nanoparticles.
3.4 Non-linear nanophotonics.

3.5 Quantum dots and nanoparticles. Single photon emission.
3.6 Metamaterials: engineering the optical properties of materials.
3.7 Examples of nanophotonic devices and applications

LEARNING ACTIVITIES AND METHODOLOGY

The teaching methodology will include:
- 40% Lectures (2.4 ECTS), where students will be presented with the basic knowledge they must acquire. Class notes will be provided to students and they will have basic reference texts that allow them to complete and delve into the different topics of the subject.
- 40% Practical classes (2.4 ECTS) aimed at solving exercises, case studies and continuous assessment.
- 20% Practices (1.2 ECTS credits), aimed at carrying out and analyzing practical cases through the use of simulation tools and class discussions.
- Tutorials Individualized assistance (individual tutorials) or in group (collective tutorials) to the students by the teaching staff

ASSESSMENT SYSTEM

% end-of-term-examination:	50
% of continuous assessment (assigments, laboratory, practicals…):	50

The assessment is based on the following criteria:
a) SIMULATION ACTIVITIES: They are compulsory. In these practices the knowledge acquired by the student will be assessed with the development of some practical cases and numerical simulations, previously studied in the theory and problems lectures. (20% of the final score).
b) CONTINUOUS ASSESSMENT ACTIVITIES: during the course several activities will be carried out both in and outside of the classroom that will have a weight of 30% of the final grade. These activities will consist of visits to research centers, class discussions, work and/or presentations of research works, etc.
c) FINAL EXAM (mandatory). The knowledge acquired by the students in each thematic block of the subject will be evaluated. This exam has a weight of 60% in the final score if the student follows the continuous assessment. On the other side, this exam will have a weight of 60% of the final mark if the student does not follow the continuous evaluation process.
Extraordinary Call
Assessment can be fitted to continuous assessment process (with the same percentages as in ordinary exam) or with a final exam with the 100% of qualification

BASIC BIBLIOGRAPHY

- George W. Hansons Fundamentals of Nanoelectronics, Pearson , 2004

- L. Novotny and B. Hetch Principles of Nano-optics, Cambridge University Press, 2012

- P.N. Prasad Nanophotonics, Wiley Interscience, 2004

- Rainer Waser Nanoelectronics and Information Technology, Wiley-VCH, 2013

ADDITIONAL BIBLIOGRAPHY

- C. Bohren, D.R. Huffman Absorption and scattering of light by small particles, John Wiley and sons, 1983

- M. Ohtsu, H. Hori Near-field nano-optics, Klumer Academics / Plenum Publishers, , 1999