



1. **Código:** 35480 **Nombre:** Ciberseguridad

2. **Créditos:** 6,00 **--Teoría:** 3,00 **--Prácticas:** 3,00 **Carácter:** Obligatorio

Titulación: 2314-Máster Universitario en Ingeniería de Telecomunicación

Módulo: 1-Módulo de Tecnologías de Telecomunicación **Materia:** 2-Telemática

Centro: E.T.S.I. DE TELECOMUNICACIÓN

3. **Coordinador:** Aragonés Lozano, Mario
Departamento: COMUNICACIONES

4. Bibliografía

Computer networks [Recurso electrónico-En línea]
Capture the Flag as Cyber Security Introduction. En: 2016 49th Hawaii
International Conference on System Sciences (HICSS), 2016, p. 5479-5486
OWASP Top 10:2025

Tanenbaum, Andrew S.
McDaniel, Lucas| Talvi, Erik| Hay, Brian

Open Worldwide Application Security Project
(OWASP)

5. Descripción general de la asignatura

Objetivos de la asignatura

En un mundo digitalmente interconectado, es crucial para un ingeniero de telecomunicaciones conocer a que riesgos de ciberseguridad se va a enfrentar en el transcurso de su día a día (tanto personal como profesional). No existe sistema que no sea susceptible de ser ciberatacado y es responsabilidad de estos ingenieros desplegar todas las salvaguardias necesarias para proteger sus sistemas. Para conseguirlo es imprescindible saber como piensa y actúa un ciberatacante y ser capaz de implementar las medidas de seguridad oportunas desde la fase de diseño de un nuevo sistema. Por todo ello, los objetivos de esta asignatura consisten en comprender de una forma más avanzada como funcionan las redes de comunicaciones IP, los protocolos de comunicaciones más empleados, los distintos sistemas operativos que se pueden encontrar en la actualidad, las vulnerabilidades más comunes en sistemas operativos y servicios, las herramientas que emplean los ciberdelincuentes para realizar sus ataques, como se realizan los ciberataques y que herramientas se pueden usar para protegerse frente a ellos.

Contextualización de la asignatura

El alumno adquirirá competencias profesionales en el ámbito de las redes de comunicaciones IP y del hacking ético.

6. Conocimientos recomendados

La asignatura tendrá como conocimientos base los adquiridos durante los estudios del Grado en Ingeniería de Telecomunicaciones relacionados con en el campo de la telemática.

7. Resultados

Resultados fundamentales

G08(GE) Capacidad para la aplicación de los conocimientos adquiridos y resolver problemas en entornos nuevos o poco conocidos dentro de contextos más amplios y multidisciplinarios, siendo capaces de integrar conocimientos.

T06(ES) Capacidad para modelar, diseñar, implantar, gestionar, operar, administrar y mantener redes, servicios y contenidos.

G12(GE) Poseer habilidades para el aprendizaje continuado, autodirigido y autónomo.

Competencias transversales

(1) Compromiso social y medioambiental

- Actividades desarrolladas relacionadas con la adquisición de la competencia

Los alumnos, organizados por grupos de trabajo, buscarán tomar el control de un sistema vulnerable mediante la ejecución de ataques a dicho sistema en un entorno controlado y analizarán las repercusiones que tendrían dichos actos si ocurriesen en un entorno real, considerando el impacto en la sociedad y la responsabilidad en la práctica profesional.

- Criterios de evaluación

Se evaluará si el alumno es capaz de comprender las consecuencias éticas de los actos realizados, considerando el impacto en la sociedad y la responsabilidad en la práctica profesional.

Resultados de Aprendizaje

RA1.1 - Valorar las consecuencias éticas de las decisiones a tomar en una situación concreta, considerando el impacto

7. Resultados

Competencias transversales

en la sociedad y la responsabilidad en la práctica profesional.

(5) Responsabilidad y toma de decisiones

- Actividades desarrolladas relacionadas con la adquisición de la competencia

Los alumnos, organizados por grupos de trabajo, deberán documentar de forma adecuada el trabajo realizado para conseguir el acceso al sistema objetivo incluyendo toda la información de los servicios de dicho sistemas y sus vulnerabilidades. Para conseguir documentar correctamente dicho trabajo, deberán consultar en fuentes externas.

- Criterios de evaluación

Se evaluará la correcta documentación del trabajo teniendo en cuenta, entre otros, que las fuentes de información escogidas sean fiables y que la información proporcionada sea completa.

Resultados de Aprendizaje

RA5.4 - Aplicar de manera efectiva técnicas relacionadas con la búsqueda bibliográfica y el uso de fuentes de datos fiables u otros sistemas de información.

8. Unidades didácticas

1. Introducción y conceptos básicos de ciberseguridad
 1. Introducción a la ciberseguridad
 2. Conceptos básicos de redes IP
 3. Introducción a los sistemas operativos
 4. Introducción a la programación
2. Ciberseguridad ofensiva
 1. Herramientas de reconocimiento y explotación
 2. Sistemas WEB
 3. CTF e informes
3. Ciberseguridad defensiva
 1. Monitorización de redes de comunicaciones IP
 2. Inteligencia de fuentes abiertas
4. Trabajos

9. Método de enseñanza-aprendizaje

Esta asignatura cuenta con las siguientes prácticas informáticas:

- Práctica 1 (4 horas): Virtualización de sistemas operativos.
 Práctica 2 (2 horas): Sistema de ficheros y comandos de Linux.
 Práctica 3 (2 horas): Reconocimiento de procesos y servicios.
 Práctica 4 (2 horas): Explotación de vulnerabilidades en servicios.
 Práctica 5 (2 horas): Escalada de privilegios en Linux.
 Práctica 6 (2 horas): WEB.
 Práctica 7 (4 horas): Desarrollo de un CTF.
 Práctica 8 (2 horas): Resolución de un CTF.
 Práctica 9 (2 horas): OSINT.

UD	TA	SE	PA	PL	PC	PI	EVA	TP	TNP	TOTAL HORAS
1	12,00	--	4,00	--	--	6,00	2,00	24,00	24,00	48,00
2	8,00	--	2,00	--	--	8,00	2,00	20,00	24,00	44,00
3	6,00	--	0,00	--	--	2,00	0,00	8,00	4,00	12,00
4	4,00	--	0,00	--	--	8,00	2,00	14,00	42,00	56,00
TOTAL HORAS	30,00	--	6,00	--	--	24,00	6,00	66,00	94,00	160,00

UD: Unidad Didáctica. TA: Teoría de Aula. SE: Seminario. PA: Práctica de Aula. PL: Práctica de Laboratorio. PC: Práctica de Campo. PI: Práctica de Informática. EVA: Actividades de Evaluación. TP: Trabajo Presencial. TNP: Trabajo No Presencial.



10. Evaluación

Descripción

	<u>Nº Actos</u>	<u>Peso (%)</u>
(05) Trabajos académicos	2	40
(15) Prueba práctica de laboratorio/campo/informática/aula	1	20
(14) Prueba escrita	2	40

La asignatura se evaluará atendiendo a los siguientes criterios:

- Dos exámenes que tendrán un peso del 40% sobre la nota final en conjunto.
- Dos trabajos académicos relacionados con el contenido de la asignatura que tendrán un peso del 40% sobre la nota final en conjunto.
- Evaluación continua de las actividades prácticas de los alumnos que tendrá un peso del 20% sobre la nota final.

De acuerdo a las directrices de evaluación del primer curso del MUIT, en caso de no asistir al mínimo de asistencia a clase exigido, la evaluación se realizará atendiendo a los siguientes criterios (alumnos sin dispensa):

- Dos exámenes que tendrán un peso del 80% sobre la nota final en conjunto.
- Evaluación continua de las actividades prácticas de los alumnos que tendrá un peso del 20% sobre la nota final.

Recuperaciones y mejora de nota:

- La nota de los exámenes puede ser recuperada y se puede subir presentándose al examen de recuperación. En caso de presentarse a dicho examen, se renuncia a la nota obtenida anteriormente.
- La nota de los trabajos académicos podrá ser recuperada y se podrá subir volviendo a presentar los mismos. En caso de volver a presentar éstos, se renuncia a la nota obtenida anteriormente.
- La evaluación continua de las actividades prácticas no es recuperable.

En caso de detección de un supuesto de fraude académico en cualquier acto de evaluación, este deberá ser motivado y documentado mediante la correspondiente acta de honestidad.

Como consecuencia académica inmediata, el acto de evaluación afectado será calificado con una puntuación de cero (0), sin perjuicio del derecho del estudiante a formular alegaciones y a interponer los recursos que procedan.

En ese caso, el profesor/a responsable de la asignatura podrá sustituir en su totalidad el sistema ordinario de evaluación por el siguiente sistema de evaluación alternativo:

1. Requerirá al estudiante la realización de una prueba de evaluación de conjunto, excluyendo la parte afectada por la incidencia. La puntuación final de la asignatura será el resultado de la evaluación ponderada por el porcentaje correspondiente al contenido de esta prueba. La parte afectada por la incidencia mantendrá la puntuación de 0 y su porcentaje original en la puntuación final.

2. Dicha prueba podrá tener carácter oral y deberá respetar los principios de objetividad y proporcionalidad. En caso de no aplicar el sistema de evaluación alternativo, se aplicará íntegramente el sistema ordinario previsto en la guía docente.

La aplicación de estas medidas es independiente, en su caso, de la posible incoación de un procedimiento disciplinario conforme a la normativa universitaria vigente

11. Porcentaje máximo de ausencia

<u>Actividad</u>	<u>Porcentaje</u>	<u>Observaciones</u>
Teoría Aula	20	
Teoría Seminario	0	
Práctica Aula	20	
Práctica Laboratorio	0	
Práctica Informática	20	
Práctica Campo	0	



1. Code: 35476 **Name:** Photonic integrated circuits

2. Credits: 6,00 **--Lecture:** 3,00 **--Practice:** 3,00 **Type of Course:** Compulsory

Degree: 2314-Master's Degree in Telecommunication Engineering

Module: 1-Telecommunication Technologies Module **Subject:** 1-Telecommunication and Multimedia Systems

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Muñoz Muñoz, Pascual

Departament: COMMUNICATIONS

4. References

5. Course outline

Course objectives

The course will educate students in the technology and business aspects of photonic integrated circuits.

Contextualization of the course

Several market reports support the statement the topics addressed in this course are of growing interest for the industry. For instance, the market report by TransparencyMarketResearch [1] states "The photonic integrated circuit market is growing at a phenomenal rate due to the significant improvements in power consumption, system size, reliability, and cost. The development in silicon photonic technology has helped in enabling large scale manufacturing of PIC products at low cost. Also, most players are developing monolithically integrated InP (Indium Phosphide) based photonic integrated circuits that can integrate more than 600 components in a single chip. Thus, there is increasing competition as players are trying to produce PIC based products at low cost."

Regarding localization of the industries where the young graduates may find a position, the report highlights "Currently, North America is the largest market for PIC based products owing to the increasing applications of optical fibers in datacenters and WAN. North America holds more than 40% share of the overall PIC market; however, Asia-Pacific is expected to emerge as a market leader in the coming years growing at a CAGR of about 35% due to the prolific growth in datacenters and access network in the region. Europe ranks second in the market for PIC products. Currently, Asia-Pacific is the largest player in access network applications of optical fiber communication."

On the other hand, the market report by Yole Development [2] states "For several years now, the silicon photonics projects have been under the umbrella of large-scale R&D projects to set up roadmaps. Today, Multi-Project Wafer services foundries are opening and more industrial foundry activities are set up. Generic technologies and generic production platforms are needed to achieve low cost/high volume. As the future lays in the separation of design and fabrication, this industry is looking for an electronics-like foundry model." and regarding the evolution of the market "Although the market will grow by a factor of 3 in 5 years, business could explode after 2020 as inter and intra-chip communications could make this market grow by a factor of 10!".

In the reports, the following companies and organizations are listed as key players: Altera, Altis, AML, Apple, Aurion, Avago, BAE Systems, Calioxia, CEA Leti, Chiral Photonics, Cisco, ColorChip, Cyoptics/InPlane, DAS Photonics, Effect Photonics, Enablance, ePIXfab, EuroPIC, EVgroup, Fraunhofer hhl, Freescale, Ghent University, IHP, Microelectronics, Fujitsu, Genalyte, Helios, HP Labs, IBM, IME (A*STAR), IMEC, Infinera, Intel, IPKISS, JePPiX, Kotura, Cisco/, LightWire, Lionix, Luxtera, MIT, Mitsubishi heavy Industries, Molex, NeoPhotonics, Northrop grumman, NTT, Nvidia, Oclaro, OneChip, Photonics, OPSIS SYSTEM, Oracle, PECST, Photline, Sandia, Skorpis Technologies, STM, Sun, SUSS MicroTec, TEEM Photonics, TI, TSMC, U2t photonics, UCSB, Stanford University, VLC Photonics, Xilinx, XIO Photonics.

The course addresses not only technical and innovative aspects of the market, i.e. PIC design for manufacturing & test, but some business and management details that are of paramount importance in a professional, i.e. how much does your chip cost, how this is related to the cost structure of your company, and how to mark it up to the a price that both generates revenue and is on-market, amongst other.

[1] Photonic Integrated Circuit Market - Global Industry Size, Share, Trends, Analysis, and Forecast, 2012 - 2018,

<http://www.transparencymarketresearch.com/photonic-integrated-circuit.html>

[2] Silicon Photonics: Big Investments, Small Business, 2012, <http://www.reportlinker.com/p01021140-summary/Silicon-Photonics-Big-Investments-Small-Business.html>

6. Recommended prior knowledge



6. Recommended prior knowledge

- a degree in Electronic Engineering or Physics is advisable.
- background in electromagnetism, optics and photonics is expected.

7. Results

Fundamental results

G01(GE) The ability to conceptualise, calculate and design products, processes and facilities in all fields of Telecommunications Engineering.

T03(ES) The ability to implement systems via cables, lines and satellites that use both fixed and mobile communication.

G08(GE) The ability to apply acquired knowledge and solve problems in new or unknown settings within wide and multidisciplinary environments while being capable of integrating knowledge.

UPV-Generic student outcomes

(1) Social and environmental commitment

- Activities carried out to achieve the student outcome
Developed and evaluated in the course materials, both in lecture room and laboratory activities.

- Assessment criteria

The transversal competences will be evaluated and graded within the written tests.

Learning Outcomes

RA1.4 - Design, develop and implement solutions in the field of the discipline that respond to social demands, taking into account the Sustainable Development Goals and global, cultural and economic factors.

(2) Innovation and creativity

- Activities carried out to achieve the student outcome
Developed and evaluated in the course materials, both in lecture room and laboratory activities.

- Assessment criteria

The transversal competences will be evaluated and graded within the written tests.

Learning Outcomes

RA2.1 - Identifying new challenges, projects or opportunities for improvement in the field of the discipline aligned with future trends and advances.

8. Syllabus

1. ECOSYSTEM

1. History, evolution, context, technologies
2. Supply chain, market trends

2. TECHNOLOGY

1. Waveguides
2. Couplers
3. Interferometers
4. Modulators
5. Filters
6. Circuit design

3. PRODUCTION

1. Introduction to manufacturing
2. Manufacturing platforms
3. Packaging & layout
4. Test and measurement

4. BUSINESS

1. Fabless model financial aspects
2. Company presentations

9. Teaching and Learning Methodologies

Lab sessions:

- Waveguides (3 sessions x 2 hours / session)
- Couplers (3 sessions x 2 hours / session)
- Interferometers and filters (3 sessions x 2 hours / session)



9. Teaching and Learning Methodologies

- Layout (3 sessions x 2 hours / session)

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	4,00	--	0,00	0,00	--	--	2,00	6,00	6,00	12,00
2	14,00	--	4,00	16,00	--	--	12,00	46,00	49,00	95,00
3	10,00	--	2,00	8,00	--	--	8,00	28,00	18,00	46,00
4	2,00	--	0,00	0,00	--	--	1,00	3,00	3,00	6,00
TOTAL HOURS	30,00	--	6,00	24,00	--	--	23,00	83,00	76,00	159,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

(15) Practical laboratory/field/computing/classroom test
(14) Written test

<u>Num. Acts</u>	<u>Weight (%)</u>
4	35
10	65

- In the case of distance students, with exemption from the obligation to attend, the evaluation will be the same than for the rest of students.
- It will be possible to recover 70% of the theory grade through 1 final written test.
- It will be possible to recover 70% of the lab grades through 1 final assignment.
- The transversal competences will be evaluated and graded within the written tests.
- The written tests will comprise a mix of on-line examinations (comprising assignments+quiz, up to 8) and written paper and pen (traditional) examinations (up to 2), to a maximum total of 10 written tests.
- The traditional examinations will comprise up to 40% of the final mark (leaving a maximum of 25% for the on-line examinations).
- A minimum mark in the (combined) traditional examinations of 4 points out of 10 is required to average with the other marks in the course.

Additional information:

1. The student may attend the resit (retake) assessment activities of the course in order to improve their final grade, which may result in an increase or a decrease of the final mark. The student must inform the teaching staff, at least 3 working days before the date of the test, of their intention to take the resit exam.
2. If the student has lost the right to be assessed in an evaluation activity due to the application of the University Coexistence and Academic Disciplinary Regulations of the Universitat Politècnica de València, they will not be eligible for continuous assessment and will instead be evaluated through a final exam covering the entire course.
3. When the student does not achieve the minimum required mark in any of the assessment activities and the overall grade, without applying the minimum mark requirement, is equal to or higher than 4 out of 10:
 - The final grade will be 4, if at least 1 out of 10 has been obtained in each of the assessment activities with a minimum mark requirement.
 - Otherwise, the final grade will be 3.
4. If, as a result of behaviours contrary to academic integrity, a student fails an assessment activity that is eligible for resit, the resit will be carried out through a final exam covering the entire course. This exam will be oral [or indicate another preferred format], and the final grade will be the one obtained in this exam.
5. If there are indications of the use of AI or other unauthorized materials during an exam or in course assignments, including practical work, the student concerned will be summoned to provide an oral defense of any of the students presented works and exams.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.



10. Assessment

2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	0	Attendance to class is not mandatory, but highly recommended to be able to do the practical work (which is mandatory)
Seminar Theory	0	Attendance to class is not mandatory, but highly recommended to be able to do the practical work (which is mandatory)
Lecture Practice	0	Attendance to class is not mandatory, but highly recommended to be able to do the practical work (which is mandatory)
Laboratory Practical	0	Attendance to class is not mandatory, but highly recommended to be able to do the practical work (which is mandatory)
Computer Practice	0	Attendance to class is not mandatory, but highly recommended to be able to do the practical work (which is mandatory)
Field Practice	0	Attendance to class is not mandatory, but highly recommended to be able to do the practical work (which is mandatory)



1. Code: 36094 **Name:** Classical and Quantum Information Theory

2. Credits: 3,00 **--Lecture:** 2,00 **--Practice:** 1,00 **Type of Course:** Compulsory

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 1-Compulsory Training

Subject: 4-Information Theory

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Macho Ortiz, Andrés

Departament: COMMUNICATIONS

4. References

Elements of information theory

Classical and quantum information theory : an introduction for the Telecom scientist

Quantum information theory

Quantum computation and quantum information

Quantum information

Cover, Thomas M.

Desurvire, Emmanuel

Wilde, Mark

Nielsen, Michael A.

Barnett, S. M.

5. Course outline

Course objectives

This course provides a comprehensive introduction to classical and quantum information theory, establishing a unified framework to understand how information is quantified, processed, and transmitted in both classical and quantum systems. The course begins with the foundations of classical information theory, including entropy measures such as Boltzmann and Shannon entropy, and their role in quantifying uncertainty and information content. Key concepts such as source coding, channel models, error rates, and fundamental theorems like the source coding theorem and the channel coding theorem are studied, with applications to modern communication systems. Building on this foundation, the course extends these ideas to the quantum domain, where information is encoded in quantum states (qubits) and governed by the principles of quantum mechanics. Topics include quantum measurements, von Neumann entropy, composite systems, and quantum operations. The course also introduces quantum communication theory, including channel capacity and the role of uniquely quantum resources such as superposition and entanglement. By integrating classical and quantum perspectives, the course highlights both the continuity and the fundamental differences between these frameworks. It provides students with the theoretical tools required to analyze hybrid classical/quantum systems and prepares them to address emerging challenges in quantum technologies and advanced communication systems.

Contextualization of the course

Information Theory. Quantum Information Theory.

6. Recommended prior knowledge

(36096) Quantum communications

7. Results

Fundamental results

RF4(GE) Evaluate the performance of quantum systems based on Quantum Information Theory.

Learning Outcomes

RA11 - State and interpret the theoretical foundation of Quantum Information Theory based on Classical Theory and the concept of entropy.

RA12 - Evaluate the performance of quantum information systems based on the corresponding figures of merit, including error correction and data compression.

UPV-Generic student outcomes

(4) Effective communication

- Activities carried out to achieve the student outcome

Project and assignment presentations.

- Assessment criteria

Observation.

Learning Outcomes



7. Results

UPV-Generic student outcomes

RA4.4 - Demonstrating proficiency in digital communication using a variety of support media adapted to the situation and audience.

(5) Responsibility and decision-making

- Activities carried out to achieve the student outcome
Homework assignments.
- Assessment criteria
Homework evaluation.

Learning Outcomes

RA5.2 - Develop and conduct practical or experimental work and research, interpreting data and drawing conclusions based on the principles of the discipline.

RA5.4 - Effectively applying techniques related to literature searching and the use of reliable data sources or other information systems.

8. Syllabus

1. Introduction.
2. Classical Information Theory.
 1. Communications, compression and fundamental limits.
 2. Entropy and mutual information.
 3. Lossless source coding.
 4. Channel capacity.
 5. Rate distortion theory and lossy source coding.
3. Quantum Information Theory.
 1. Quantum communication system.
 2. Generalized quantum measurements.
 3. Von Neumann entropy.
 4. State comparative parameters.
 5. Quantum noise and operations.
 6. Quantum communication theory: channel capacity.

9. Teaching and Learning Methodologies

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	1,00	--	1,00	--	--	0,00	--	2,00	2,00	4,00
2	9,00	--	2,00	--	--	2,00	1,00	14,00	22,00	36,00
3	10,00	--	2,00	--	--	3,00	1,00	16,00	30,00	46,00
TOTAL HOURS	20,00	--	5,00	--	--	5,00	2,00	32,00	54,00	86,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

	<u>Num. Acts</u>	<u>Weight (%)</u>
(05) Academic work	1	30
(15) Practical laboratory/field/computing/classroom test	1	15
(14) Written test	2	50
(11) Observation	1	5

The course assessment consists of the following evaluation activities: academic work (30%), observation-based assessment (5%), two written examinations (50%), and practical laboratory/computing activities (15%).

The written assessment component is divided into two written examinations with weights of 20% and 30%, respectively. The



10. Assessment

second written examination is subject to a minimum required mark of 4.0 out of 10. If this minimum is not achieved, and the weighted average without applying this requirement is at least 4.0, the final grade will be 4.0 provided that a minimum mark of 1.0 has been obtained in all such assessment components; otherwise, the final grade will be 3.0.

In the resit examination period, students may take a comprehensive examination accounting for 100% of the final grade, which replaces the continuous assessment components and ensures the possibility of recovering all assessment components with a weight equal to or greater than 30% of the final grade.

Students who have passed the continuous assessment activities and wish to improve their final grade through the resit examination must request it from the course coordinator at least three working days before the examination date, following the procedure established by the teaching staff or, otherwise, by email sent to the official university address. In this case, the grade obtained in the resit examination will replace the previous final grade.

Students officially granted academic dispensation are exempted from attending classes and practical sessions. However, they must submit all projects and assignments and complete all assessment activities under the same conditions and within the same deadlines as the rest of the students.

The practical laboratory/computing activity consists of a 5-hour project entitled "Design of a Classical-to-Quantum Information System". In this activity, students will design and analyze a complete quantum information system intended to transmit classical information, including the definition and implementation of the main functional blocks of the communication chain.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.

2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	90	
Seminar Theory	90	
Lecture Practice	90	
Laboratory Practical	90	
Computer Practice	90	
Field Practice	90	



1. Code: 36100 **Name:** Electronics for Quantum Systems

2. Credits: 3,00 **--Lecture:** 2,00 **--Practice:** 1,00 **Type of Course:** Elective

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 2-Elective Courses and Externships

Subject: 8-Elective Courses and Externships

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Gómez Hernández, Víctor Jesús

Departament: APPLIED PHYSICS

4. References

Epitaxy

Epitaxy of Semiconductors : Introduction to Physical Principles

Low-Dimensional Solids

Advances in Cryogenic Engineering (AIP Conference Proceedings, volumen 985, número 1)

Advances in Cryogenic Engineering Materials

Miao Zhong

Pohl, Udo W.

Bruce, Duncan W| O'Hare, Dermot| Walton,

Richard I

Weisend, J. G.

Summers, Leonard T

5. Course outline

Course objectives

Electronics for Quantum Systems examines the principles and applications of electronics within the field of quantum technologies. The course covers foundational concepts such as low dimensionality in solids, and quantum confinement, extending to advanced platforms for quantum electronics like quantum dots, nanowires, nanoparticles and 2D materials (like graphene). It also explores practical laboratory techniques in epitaxy, 2D materials, and cryogenics. Through this comprehensive study, students will gain the expertise to design and analyze electronic components crucial for quantum information and photonics, preparing them for cutting-edge research and development in quantum technologies.

Contextualization of the course

This course bridges classical electronics with quantum-scale phenomena, focusing on the electronic principles and materials that underlie modern quantum devices. Students will explore low-dimensional systems such as quantum wells, wires, and dots, which form the basis for quantum confinement and novel quantum behaviors. These systems are essential for the realization of qubits, quantum transistors, and other components in emerging quantum computing platforms.

Additionally, the course delves into cutting-edge materials and structures, including topological insulators and Majorana fermion-based systems, which offer robust and fault-tolerant pathways toward scalable quantum computation. The inclusion of ultra-cold atoms and hybrid platforms highlights the interdisciplinary nature of modern quantum systems, where electronic control and quantum coherence must coexist under extreme physical conditions.

To equip students with practical skills, the subject also covers laboratory techniques crucial to the fabrication and characterization of quantum devices. This includes epitaxy for material growth, cryogenics for low-temperature operation, and the application of magnetic fields; all integral to the design and performance of electronic components in quantum technologies.

By integrating theoretical understanding with practical insights, Electronics for Quantum Systems prepares students to contribute to the development of next-generation quantum technologies. It lays the groundwork for careers in academic research, advanced engineering, and the quantum tech industry, where expertise in electronic control of quantum systems is both essential and highly sought after.

6. Recommended prior knowledge

(36091) Solid State Physics



7. Results

UPV-Generic student outcomes

(4) Effective communication

- Activities carried out to achieve the student outcome

Students will conduct a mini-research project investigating a current or emerging challenge in the field of quantum electronics. This includes identifying an open problem, analyzing the state of the art, and proposing a potential direction or framework for addressing it. The goal is to study a real-world research context where both analytical thinking and scientific communication are essential.

Objectives Addressed:

Learning Result 1: Demonstrate proficiency in digital communication using a variety of support media adapted to the situation and audience.

Learning Result 2: Identify, formulate and solve complex problems autonomously, applying the principles of the discipline.

Activity Details:

1. Topic Selection and Problem Identification:

- o Students choose a research problem related to electronics in quantum systems.
- o They must clearly define the research question or challenge and justify its relevance.

2. Literature Review and Critical Analysis:

- o Conduct a focused review of recent academic literature (e.g., journal articles, conference proceedings, preprints).
- o Summarize the current approaches, highlight unresolved issues, and identify technological or theoretical gaps.

3. Digital Poster or Infographic (Communication Output):

- o Students create a digital poster to summarize their research findings, aimed at a non-specialist but scientifically literate audience.

Introduction to the problem and context

Review of current approaches

Identification of limitations

A proposed direction or framework for addressing the challenge

- o Visual materials such as figures, conceptual diagrams, and tables are encouraged.
- o Posters will be presented in a short pitch during a class mini-conference.

- Assessment criteria

For Learning Result 1 (Communication):

- o Clarity and impact of the research poster
- o Structure and depth
- o Effectiveness in communicating to both technical and non-technical audiences
- o Use of digital tools and visual media appropriately
- o Evaluation by peers will be included

Learning Outcomes

RA4.4 - Demonstrating proficiency in digital communication using a variety of support media adapted to the situation and audience.

(5) Responsibility and decision-making

- Activities carried out to achieve the student outcome

With the previous activity both learning results will be evaluated.

- Assessment criteria

For Learning Result 2 (Problem Solving):

- o Relevance and originality in problem selection
- o Rigor in literature review and analysis
- o Insightfulness in identifying research gaps
- o Justification and feasibility of proposed research direction

Learning Outcomes

RA5.1 - Identify, formulate and solve complex problems autonomously, applying the principles of the discipline.

8. Syllabus

1. Introduction: Low dimensionality in solids. Topology. Quantum confinement. Topological materials. Qubits. Nanoelectronics.
2. Low dimensionality systems: Quantum Dots, Nanowires, Quantum wells, Nanoparticles, 2D materials
3. Platforms for quantum electronics: Semiconductor Quantum Dot Platforms, Semiconductor Nanowire Platforms, 2D Material Platforms
4. Laboratory practical aspects: Epitaxy, 2D optomechanical resonators



8. Syllabus

5. LAB1: Nanoresonators
6. LAB2: Epitaxy
7. Poster session

9. Teaching and Learning Methodologies

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	2,00	--	--	--	--	--	0,50	2,50	5,00	7,50
2	5,00	--	1,00	0,00	--	--	0,50	6,50	10,00	16,50
3	5,00	--	1,00	0,00	--	--	0,50	6,50	10,00	16,50
4	8,00	--	3,00	0,00	--	--	1,00	12,00	15,00	27,00
5	--	--	--	1,00	--	--	0,50	1,50	1,00	2,50
6	--	--	--	2,00	--	--	0,50	2,50	1,00	3,50
7	--	--	--	2,00	--	--	2,00	4,00	8,00	12,00
TOTAL HOURS	20,00	--	5,00	5,00	--	--	5,50	35,50	50,00	85,50

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

- (05) Academic work
- (15) Practical laboratory/field/computing/classroom test
- (14) Written test
- (11) Observation

Num. Acts Weight (%)

1	20
1	20
2	50
1	10

Assessment Criteria:

Academic Work: 20%

This includes the poster presentation, and peer evaluation.

Observation: 10%

Participation during the lectures and solution of proposed problems.

Written Exam: 50%

Multiple-choice written exam covering theoretical and practical content (theory and classroom practice, plus lab-related questions). The theoretical content is evaluated in one exam that counts for a 40% and another one to evaluate the practical content for a total of 10% of the final grade.

Practical test: 20%

Short-answer or multiple-choice quizzes aimed at promoting continuous learning.

In the event of failing the written exam, it can be retaken within the period allotted for retaking exams.

In the event of failing the Academic Work, the student will have the opportunity to amend the poster and submit again for reassessment.

Students who have passed the written exam and wish to retake it to improve their final grade may do so by specifying in advance that they wish to improve their grade.

IMPORTANT: The retake grade will be considered for the final grade, even if it is lower than the grade obtained in the exam taken throughout the course.

In the event of an exemption from attendance, the student will only have to complete the written exam for the evaluation of the subject.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the



10. Assessment

following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.
 2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.
- The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	0	
Seminar Theory	0	
Lecture Practice	0	
Laboratory Practical	0	
Computer Practice	0	
Field Practice	0	



1. Code: 36097 **Name:** Photonic integrated circuits

2. Credits: 3,00 **--Lecture:** 1,50 **--Practice:** 1,50 **Type of Course:** Compulsory

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 1-Compulsory Training

Subject: 7-Integrated Photonics

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Muñoz Muñoz, Pascual

Departament: COMMUNICATIONS

4. References

5. Course outline

Course objectives

The course ¿Integrated Photonics Signal Processing¿ introduces students to the design and implementation of integrated photonic circuits for signal processing applications. The course is divided into two main parts:

Part 1. Photonic Chip Design: Focused on the fundamental building blocks of photonic circuits ¿waveguides, couplers, interferometers, modulators¿ and the use of PDKs and compact models for simulation and layout using the gdsfactory framework.

Part 2. Programmable Photonics: Introduction to reconfigurable photonic systems, microwave photonics applications, and integrated waveguide meshes for advanced signal processing functions.

Contextualization of the course

Integrated photonics has become a core enabling technology in a variety of fields, from high-speed communications and sensing to emerging applications in quantum computing and artificial intelligence. Signal processing on photonic chips offers unmatched performance in terms of bandwidth, latency, and energy efficiency. While Application Specific Photonic Integrated Circuits (ASPICs) provide custom solutions for large-scale deployments, recent advances in programmable photonics have unlocked new paradigms of reusability, flexibility, and scalability. Technologies such as reconfigurable interferometric meshes and tunable photonic cores are key enablers for agile systems in data centers, wireless fronthaul, neuromorphic computing, and quantum signal processing.

This course addresses both traditional and programmable approaches to PIC-based signal processing, combining foundational knowledge with hands-on experience using widely adopted open-source tools. It prepares students to contribute to multidisciplinary teams in industry or research, supporting the rapid evolution of integrated photonics platforms.

6. Recommended prior knowledge

- * Background in electromagnetism, optics, and photonics
- * Basic knowledge of electronic circuits and signal processing

7. Results

Fundamental results

RF7(GE) Develop integrated photonic structures for signal processing applications.

Learning Outcomes

R18 - Formulate optical signal processing techniques.

R19 - Design and program various integrated photonic structures, such as photonic circuits, optical matrices, and multiport interferometric devices.

UPV-Generic student outcomes

(2) Innovation and creativity

- Activities carried out to achieve the student outcome
Developed and evaluated in the course materials, both in lecture room and laboratory activities.

- Assessment criteria

The transversal competences will be evaluated and graded within the written tests.

Learning Outcomes

RA2.4 - Demonstrating an entrepreneurial attitude in the design, development and implementation of solutions that represent a novelty or advance in the field of the discipline.



7. Results

UPV-Generic student outcomes

(4) Effective communication

- Activities carried out to achieve the student outcome
Developed and evaluated in the course materials, both in lecture room and laboratory activities.
- Assessment criteria
The transversal competences will be evaluated and graded within the written tests.

Learning Outcomes

- RA4.1 - Structuring the discourse to favour the understanding of the objectives, actions and/or results of their work.
- RA4.2 - Developing professional texts or scientific-technical reports according to the conventions of the discipline.

8. Syllabus

1. Photonic Chip Design
 1. Waveguides: theory, design, and simulation
 2. Couplers: directional, MMI; modeling and simulation
 3. Interferometers: MZI, resonators, filters
 4. Compact models and circuit modeling I
 5. Compact models and circuit modeling II
 6. Fabrication platforms, fabless model, PDKs
2. Programmable Photonics
 1. Introduction to programmable photonic systems
 2. Basic building blocks and multi-port interferometers
 3. Reconfigurable Application-Specific Photonic Integrated Circuits: Applications
 4. Reconfigurable photonic meshes

9. Teaching and Learning Methodologies

Lab sessions:

Waveguides & Couplers I

Waveguides & Couplers II

Compact models and circuit modeling I

Compact models and circuit modeling II

Reconfigurable circuits I

Reconfigurable circuits II

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	7,50	--	2,50	2,50	--	2,50	0,00	15,00	25,00	40,00
2	7,50	--	2,50	2,50	--	2,50	0,00	15,00	25,00	40,00
TOTAL HOURS	15,00	--	5,00	5,00	--	5,00	0,00	30,00	50,00	80,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

- (15) Practical laboratory/field/computing/classroom test
- (14) Written test

Num. Acts Weight (%)

4	35
10	65

- In the case of distance students, with exemption from the obligation to attend, the evaluation will be the same than for the rest of students.
- It will be possible to recover 70% of the theory grade through 1 final written test.



10. Assessment

- It will be possible to recover 70% of the lab grades through 1 final assignment.
- The transversal competences will be evaluated and graded within the written tests.
- The written tests will comprise a mix of on-line examinations (comprising assignments+quiz, up to 8) and written paper and pen (traditional) examinations (up to 2), to a maximum total of 10 written tests.
- The traditional examinations will comprise up to 40% of the final mark (leaving a maximum of 25% for the on-line examinations).
- A minimum mark in the (combined) traditional examinations of 4 points out of 10 is required to average with the other marks in the course.

Additional information:

1. The student may attend the resit (retake) assessment activities of the course in order to improve their final grade, which may result in an increase or a decrease of the final mark. The student must inform the teaching staff, at least 3 working days before the date of the test, of their intention to take the resit exam.
2. If the student has lost the right to be assessed in an evaluation activity due to the application of the University Coexistence and Academic Disciplinary Regulations of the Universitat Politècnica de València, they will not be eligible for continuous assessment and will instead be evaluated through a final exam covering the entire course.
3. When the student does not achieve the minimum required mark in any of the assessment activities and the overall grade, without applying the minimum mark requirement, is equal to or higher than 4 out of 10:
 - The final grade will be 4, if at least 1 out of 10 has been obtained in each of the assessment activities with a minimum mark requirement.
 - Otherwise, the final grade will be 3.
4. If, as a result of behaviours contrary to academic integrity, a student fails an assessment activity that is eligible for resit, the resit will be carried out through a final exam covering the entire course. This exam will be oral [or indicate another preferred format], and the final grade will be the one obtained in this exam.
5. If there are indications of the use of AI or other unauthorized materials during an exam or in course assignments, including practical work, the student concerned will be summoned to provide an oral defense of any of the students presented works and exams.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.
 2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.
- The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	100	Attendance to class is not mandatory, but highly recommended to be able to do the practical work (which is mandatory)
Seminar Theory	100	
Lecture Practice	100	Attendance to class is not mandatory, but highly recommended to be able to do the practical work (which is mandatory)
Laboratory Practical	100	Attendance to class is not mandatory, but highly recommended to be able to do the practical work (which is mandatory)
Computer Practice	100	Attendance to class is not mandatory, but highly recommended to be able to do the practical work (which is mandatory)
Field Practice	100	



1. Código: 35475 **Nombre:** Inteligencia artificial para sistemas de comunicaciones y multimedia

2. Créditos: 6,00 **--Teoría:** 3,00 **--Prácticas:** 3,00 **Carácter:** Obligatorio

Titulación: 2314-Máster Universitario en Ingeniería de Telecomunicación

Módulo: 1-Módulo de Tecnologías de Telecomunicación **Materia:** 1-Sistemas de Telecomunicación y Audiovisuales

Centro: E.T.S.I. DE TELECOMUNICACIÓN

3. Coordinador: Gosálbez Castillo, Jorge

Departamento: COMUNICACIONES

4. Bibliografía

Introduction to machine learning with Python : a guide for data scientists
Deep learning
Deep learning con Python

Müller, Andreas C.
Goodfellow, Ian
Chollet, François

5. Descripción general de la asignatura

Objetivos de la asignatura

El objetivo general de la asignatura es introducir al alumno las bases de la inteligencia artificial centrada en el aprendizaje máquina. Se profundizará en los aspectos teóricos de los algoritmos de aprendizaje automático ilustrando dichos aspectos con la resolución de problemas que se plantean en aplicaciones multimedia y de telecomunicaciones con el fin de que el alumno sea capaz de plantear una solución a problemas concretos basada en este tipo de algoritmos.

Aunque la asignatura es teórico-práctica, uno de los objetivos primordiales es ayudar al alumno a que se desenvuelva adecuadamente con las herramientas necesarias para la resolución de problemas por lo que el carácter de la misma será eminentemente práctico empleando el lenguaje de programación Python y librerías open source como scikit-learn, Tensorflow y Keras entre otras.

Contextualización de la asignatura

La asignatura pertenece a la materia de Sistemas de Telecomunicación y Audiovisuales y contempla los siguientes descriptores: Técnicas de aprendizaje automático y aprendizaje profundo aplicadas a la solución de problemas de sistemas de comunicaciones y sistemas multimedia (clasificación de señales, predicción de localización de usuarios, análisis de imágenes, etc...). Tratamiento estadístico de datos

6. Conocimientos recomendados

Conocimientos de matemáticas:
- Operaciones con matrices
- Derivadas de varias variables
- Geometría

Conocimientos de programación:
- Programación en Python



7. Resultados

Resultados fundamentales

G08(GE) Capacidad para la aplicación de los conocimientos adquiridos y resolver problemas en entornos nuevos o poco conocidos dentro de contextos más amplios y multidisciplinares, siendo capaces de integrar conocimientos.

T01(ES) Capacidad para aplicar métodos de la teoría de la información, la modulación adaptativa y codificación de canal, así como técnicas avanzadas de procesamiento digital de señal a los sistemas de comunicaciones y audiovisuales.

G11(GE) Capacidad para saber comunicar (de forma oral y escrita) las conclusiones- y los conocimientos y razones últimas que las sustentan- a públicos especializados y no especializados de un modo claro y sin ambigüedades.

Competencias transversales

(1) Compromiso social y medioambiental

- Actividades desarrolladas relacionadas con la adquisición de la competencia

Análisis de aspectos éticos y de compromiso social en inteligencia artificial. Casos de uso

- Criterios de evaluación

Test o trabajo de respuesta abierta

Resultados de Aprendizaje

RA1.3 - Demostrar concienciación sobre el respeto a la diversidad y a los principios de accesibilidad universal y diseño para todas las personas.

(2) Innovación y creatividad

- Actividades desarrolladas relacionadas con la adquisición de la competencia

Trabajo de la asignatura en que deben aplicar no solo los aspectos técnicos aprendidos sino también la innovación y creatividad para plantear la solución

- Criterios de evaluación

Presentación oral

Resultados de Aprendizaje

RA2.3 - Evaluar, de manera crítica y constructiva, las ventajas y las oportunidades de diferentes soluciones a un mismo problema.

8. Unidades didácticas

1. Introducción a la inteligencia artificial
2. Análisis exploratorio de datos
 1. P1 - Análisis exploratorio de datos (EDA)
3. Extracción de características
4. Reducción de la dimensionalidad
 1. P2 - Extracción de características y reducción de la dimensionalidad para visualización y clasificación
5. Aprendizaje supervisado
 1. P3 - Clasificadores supervisados para regresión
6. Aprendizaje no supervisado
 1. P4 - Clasificadores no supervisados difusos - Segmentación de imágenes
7. Redes neuronales e hiperparámetros
 1. P5 - Redes neuronales e hiperparámetros para entrenamiento y clasificación
8. Aprendizaje profundo
 1. P6 - Deep learning - Detección de barcos
 2. P7 - Deep learning - Localización de fuentes
9. Otros aspectos prácticos en inteligencia artificial
10. P8 - Presentación y defensa del trabajo

9. Método de enseñanza-aprendizaje

<u>UD</u>	<u>TA</u>	<u>SE</u>	<u>PA</u>	<u>PL</u>	<u>PC</u>	<u>PI</u>	<u>EVA</u>	<u>TP</u>	<u>TNP</u>	<u>TOTAL HORAS</u>
1	1,00	--	--	--	--	--	--	1,00	1,00	2,00
2	2,50	--	0,50	--	--	3,00	0,00	6,00	10,00	16,00
3	2,50	--	0,50	--	--	0,00	0,00	3,00	15,00	18,00



9. Método de enseñanza-aprendizaje

<u>UD</u>	<u>TA</u>	<u>SE</u>	<u>PA</u>	<u>PL</u>	<u>PC</u>	<u>PI</u>	<u>EVA</u>	<u>TP</u>	<u>TNP</u>	<u>TOTAL HORAS</u>
4	2,50	--	0,50	--	--	3,00	0,00	6,00	10,00	16,00
5	3,50	--	0,50	--	--	3,00	0,00	7,00	15,00	22,00
6	3,50	--	0,50	--	--	3,00	0,00	7,00	15,00	22,00
7	3,50	--	0,50	--	--	3,00	0,00	7,00	5,00	12,00
8	7,50	--	2,50	--	--	6,00	0,00	16,00	15,00	31,00
9	3,50	--	0,50	--	--	0,00	0,00	4,00	2,00	6,00
10	--	--	0,00	--	--	3,00	--	3,00	20,00	23,00
TOTAL HORAS	30,00	--	6,00	--	--	24,00	0,00	60,00	108,00	168,00

UD: Unidad Didáctica. TA: Teoría de Aula. SE: Seminario. PA: Práctica de Aula. PL: Práctica de Laboratorio. PC: Práctica de Campo. PI: Práctica de Informática. EVA: Actividades de Evaluación. TP: Trabajo Presencial. TNP: Trabajo No Presencial.

10. Evaluación

<u>Descripción</u>	<u>Nº Actos</u>	<u>Peso (%)</u>
(05) Trabajos académicos	1	50
(15) Prueba práctica de laboratorio/campo/informática/aula	7	10
(14) Prueba escrita	2	40

La evaluación del contenido constará de tres partes:

- Evaluación de aprovechamiento de las prácticas informáticas (10% de la nota). Se evaluarán mediante un breve cuestionario al final de cada sesión de cada práctica.
- Evaluación de contenidos teórico-prácticos (40% de la nota). Se evaluarán mediante dos pruebas escritas (20% y 20%) en las fechas establecidas por la escuela.
- Evaluación del trabajo (50% de la nota). Se evaluará el código (25%) y una presentación oral del mismo (25%).

Los alumnos que hayan suspendido la asignatura podrán recuperar la evaluación de los contenidos teórico-prácticos (40%) junto con la evaluación del trabajo (50%) en un acto único en la fecha establecida por la escuela para tal fin. Los estudiantes que, teniendo aprobados los actos de evaluación continua, quieran presentarse a la recuperación para mejorar su calificación final deben solicitarlo al profesor responsable de la asignatura. La solicitud se realizará al menos 3 días hábiles antes de la fecha de la prueba, mediante el envío de un correo electrónico desde PoliformaT, con el destinatario a "Rol profesor" y seleccionando "Con copia a las direcciones de correo de los destinatarios". Se mantendrá la última nota obtenida, independientemente de que sea peor que la obtenida anteriormente.

En el caso de alumnos con dispensa de la obligación de asistencia, la evaluación se realizará mediante el mismo tipo de actos de evaluación que los de los alumnos presenciales, salvo el 10% de la nota asociado a la "Evaluación de aprovechamiento de las prácticas informáticas", que se integrará en la "Evaluación de contenidos teórico-prácticos", lo que hará que esta última evaluación pase del 40% al 50%.

Si un alumno ha perdido el derecho a ser evaluado en un acto de evaluación por aplicación de la Normativa de Integridad Académica (NIA), no podrá acogerse a la evaluación continua y deberá realizar una prueba final correspondiente al 100% .

En caso de detección de un supuesto de fraude académico en cualquier acto de evaluación, este deberá ser motivado y documentado mediante la correspondiente acta de honestidad.

Como consecuencia académica inmediata, el acto de evaluación afectado será calificado con una puntuación de cero (0), sin perjuicio del derecho del estudiante a formular alegaciones y a interponer los recursos que procedan.

En ese caso, el profesor/a responsable de la asignatura podrá sustituir en su totalidad el sistema ordinario de evaluación por el siguiente sistema de evaluación alternativo:

1. Requerirá al estudiante la realización de una prueba de evaluación de conjunto, excluyendo la parte afectada por la incidencia. La puntuación final de la asignatura será el resultado de la evaluación ponderada por el porcentaje correspondiente al contenido de esta prueba. La parte afectada por la incidencia mantendrá la puntuación de 0 y su porcentaje original en la



10. Evaluación

puntuación final.

2. Dicha prueba podrá tener carácter oral y deberá respetar los principios de objetividad y proporcionalidad. En caso de no aplicar el sistema de evaluación alternativo, se aplicará íntegramente el sistema ordinario previsto en la guía docente.

La aplicación de estas medidas es independiente, en su caso, de la posible incoación de un procedimiento disciplinario conforme a la normativa universitaria vigente

11. Porcentaje máximo de ausencia

<u>Actividad</u>	<u>Porcentaje</u>	<u>Observaciones</u>
Teoría Aula	0	
Teoría Seminario	0	
Práctica Aula	20	Habrà que asistir como mínimo al 80% para optar al 10% de evaluación por aprovechamiento de prácticas
Práctica Laboratorio	0	
Práctica Informática	0	
Práctica Campo	0	



1. Code: 36105 **Name:** Master's Thesis

2. Credits: 12,00 **--Lecture:** ,00 **--Practice:** 12,00 **Type of Course:** Compulsory

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 3-Master's Thesis

Subject: 9-Master's Thesis

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Ortega Tamarit, Beatriz

Departamento: COMUNICACIONES

4. References

5. Course outline

Course objectives

Under UPV framework regulations, the Master's Thesis is defined as "an autonomous activity of the student with the support of one or more tutors where the final result must always be an individual work of the student, defended in front of a panel". It is, therefore, an original exercise to be carried out individually and presented and defended in front of a university committee, consisting of a project in the field of Quantum Information and Photonics in which the skills acquired in the courses are synthesized and integrated. The training (12 ECTS) will consist mainly of the student's autonomous work.

Contextualization of the course

The Master's Thesis represents the final stage of the student's academic training. It is an original piece of work with either a research-based or professional focus, related to the subjects studied in the program. In it, the student will apply the knowledge and skills acquired along the Master program in order to achieve the proposed objectives.

6. Recommended prior knowledge

7. Results

UPV-Generic student outcomes

- (1) Social and environmental commitment
 - Activities carried out to achieve the student outcome
 - Assessment criteria
- (2) Innovation and creativity
 - Activities carried out to achieve the student outcome
 - Assessment criteria
- (3) Teamwork and leadership
 - Activities carried out to achieve the student outcome
 - Assessment criteria
- (4) Effective communication
 - Activities carried out to achieve the student outcome
 - Assessment criteria
- (5) Responsibility and decision-making
 - Activities carried out to achieve the student outcome
 - Assessment criteria



8. Syllabus

9. Activities

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
TOTAL HOURS	--	--	--	--	--	--	--	--	--	0,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

	<u>Num. Acts</u>	<u>Weight (%)</u>
(09) Project	80	80
(01) Oral examination/defense	20	20

The Master's Thesis will be evaluated by a panel made up of professors from the Master Program in the Telecommunications Faculty. The following aspects will be taken into account: - The work carried out by the student: willingness, personal capacity, technical capacity, originality and innovation in the subject, work management, conclusions and future lines. - The report or report presented by the student: organization of the memory, clarity and correctness in the expression, content of the work, etc. - The presentation and defense of the work.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.

2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	0	
Seminar Theory	0	
Lecture Practice	0	
Laboratory Practical	0	
Computer Practice	0	
Field Practice	0	



1. Code: 36095 **Name:** Open Quantum Systems And Thermodynamics I

2. Credits: 3,00 **--Lecture:** 1,50 **--Practice:** 1,50 **Type of Course:** Compulsory

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 1-Compulsory Training

Subject: 5-Open Quantum Systems And Thermodynamics

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Garcia March, Miguel Angel

Departament: APPLIED MATHEMATICS

4. References

5. Course outline

Course objectives

Open Quantum Systems is a subject that studies quantum systems interacting with an external environment. Unlike closed quantum systems, which evolve unitarily and are isolated from the outside world, open quantum systems account for decoherence, dissipation, and irreversible processes due to this interaction. Open quantum systems bridge idealized quantum mechanics and real-world systems by incorporating interaction with the environment. The subject is essential for understanding realistic quantum technologies, decoherence, and thermodynamic behavior in quantum contexts. The objectives are the following: 1) Understand the Mathematical foundations and learn the physical motivations for studying open quantum systems; 2) Learn the Mathematical Formalism: density matrix formalism and partial trace, Hilbert and Banach space, system-Environment Interactions, interactions between a quantum system and its environment, entanglement and decoherence; 3) Derive Master Equations under various approximations (Born, Markov, weak coupling) and Lindblad-form master equations for simple systems; Understand how to derive them from first principles (in some systems from second quantization models); 4) Learn how to solve and study some realistic but simple applications; 5) Connect with Thermodynamics and Information Theory: explore entropy production, quantum thermodynamic laws, and fluctuation theorems.

Contextualization of the course

Standard quantum mechanics typically assumes closed, isolated systems that evolve unitarily. But in reality, no system is truly isolated. Interactions with an external environment (heat bath, vacuum fluctuations, measurement devices) are unavoidable. These interactions lead to decoherence, dissipation, and noise, necessitating a new formalism beyond Schrödinger's equation. Secondly, open quantum systems approach help explain how classical behavior emerges from quantum systems (decoherence). Moreover, it provides a framework for understanding real quantum technologies and quantum information theory. In modern physics and quantum technologies: a) it is essential for understanding and mitigating decoherence in quantum computers and sensors; b) it is central to modeling open quantum dynamics in condensed matter systems, atomic physics, and optomechanics; 3) it plays a role for the analysis of e.g. quantum feedback, control, time in quantum mechanics. It is crucial for a theory of measurement; and objectivity. A course in Open Quantum Systems provides the connection between idealized quantum theory and real-world quantum phenomena, equipping students with the tools to understand and design systems that function in the presence of environment-induced noise and decoherence.

6. Recommended prior knowledge

(36092) Quantum Photonics

(36093) Quantum computing and programming

(36094) Classical and Quantum Information Theory

Knowledge of Advanced quantum mechanics, Statistical mechanics and thermodynamics (Ensembles - microcanonical, canonical, etc. -, Entropy, temperature, and equilibrium, irreversibility, partition functions and thermal states) would be useful. Also Linear Algebra (Vector spaces, inner products, Matrices, eigenvalues, eigenvectors, Tensor products, Unitary and Hermitian operators, Diagonalization and spectral decomposition); Other useful mathematical tools: Ordinary and partial differential equations, Fourier/Laplace transforms, complex variable, Probability theory and generally calculus. Also numerical methods and programming in python. Concepts from quantum optics, like coherent states, etc.



7. Results

Fundamental results

RF6(GE) Analyse open quantum systems from quantum thermodynamics.

Learning Outcomes

RA16 - Model an open quantum system in contact with an environment, and identify the relevant information from the resulting master equations.

RA17 - Analyze quantum systems from a thermodynamic perspective and out-of-equilibrium dynamics.

UPV-Generic student outcomes

(1) Social and environmental commitment

- Activities carried out to achieve the student outcome

Presentations in class of a short bibliographic search, small essay, work on some scientific paper, or calculation of a simple system.

- Assessment criteria

Evaluation time effort, originality, interest shown, understanding of complex concepts from the subjects and its application, and way of presenting, interaction with colleagues during questions made by whole class.

Learning Outcomes

RA1.3 - Demonstrating awareness of respect for diversity and the principles of universal accessibility and design for all people.

RA1.4 - Design, develop and implement solutions in the field of the discipline that respond to social demands, taking into account the Sustainable Development Goals and global, cultural and economic factors.

(3) Teamwork and leadership

- Activities carried out to achieve the student outcome

Small exercises done in class during teaching in groups of two.

- Assessment criteria

Questions from professor to explain to which conclusions the team has arrived. Collaboration of both students, politeness, respect for each other ideas will be very valued. Working in a team is very important for research, and it's crucial to be respectful.

Learning Outcomes

8. Syllabus

1. Introduction to Density Matrix Formalism, Composite Systems and Entanglement, and Quantum Operations
 1. Pure and Mixed states
 2. Differential operators: operator formalism and its usefulness
 3. Density matrix formalism
 4. Practical session: Introduction to qutip
2. Derivation of Master equations and open quantum system formalism
 1. Von-Neumann or Liouville equation: Heisenberg and interaction picture
 2. Dynamical maps for the dynamics of reduced open quantum system
 3. Microscopic derivation of Master equation: Making practical quantum Master equation
 4. Practical session: Vacuum Rabi oscillations in the Jaynes-Cummings model
3. Solving Master equations
 1. Techniques for solving Lindblad equations
 2. Tutorial on Qutip
 3. Practical session: Master Equation Solver: Single-Qubit Dynamics and Vacuum Rabi oscillations
4. Some simple applications
 1. The quantum optical master equation
 2. Decay of two-level atom in a thermal bath and squeezed vacuum
 3. Resonance fluorescence
 4. Practical session: Single-Atom-Lasing
5. Connections to quantum thermodynamics and information theory
 1. Open systems in thermal environments
 2. Quantum entropy production
 3. Work, heat, and fluctuation theorems



8. Syllabus

4. Practical Session: The Dicke model

9. Teaching and Learning Methodologies

The computer sessions are the practical sessions.

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	3,00	--	2,00	--	--	1,00	1,00	7,00	10,00	17,00
2	3,00	--	2,00	--	--	1,00	1,00	7,00	10,00	17,00
3	3,00	--	2,00	--	--	1,00	1,00	7,00	10,00	17,00
4	3,00	--	2,00	--	--	1,00	1,00	7,00	10,00	17,00
5	3,00	--	2,00	--	--	1,00	1,00	7,00	10,00	17,00
TOTAL HOURS	15,00	--	10,00	--	--	5,00	5,00	35,00	50,00	85,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

	<u>Num. Acts</u>	<u>Weight (%)</u>
(05) Academic work	2	50
(15) Practical laboratory/field/computing/classroom test	1	10
(14) Written test	2	30
(11) Observation	1	10

- The written exams will be two tests. Each for a 15% of the final grade.
- The projects are divided in two parts, each for a 25% of the final grade. The projects serve also to evaluate the practical sessions, as it should include programming with qutip.
- Then, the ordinary acts are (each partial) a test (15%) and first part of project (25%).
- If the grading is smaller than 5, the student has to do a final exam. This will have two parts, corresponding to the contents of the two test exams. The first part corresponds to the first partial grading (and substitutes first part of project and first test, that is 25%+15%=40%) and second part corresponds to the second partial grading (and substitutes second part of project and second test, that is 25%+15%=40%). The student can choose to attend the first of second part to increase the grading or to be able to pass the subject, if the grading is smaller than 5. The best grading is the final grading.

In the case of students with exemption, the distribution will be:

- 2 test exams (40%+40% of the final grading). If the student does not pass, there will be a final exam for each of the test exams.
- One exam to evaluate the practical sessions with qutip (20% final grading). This exam cannot be repeated, nor does it have minimal grading.

For every test exam, if the grading is smaller than 3 over 10, the student must attend the corresponding final exam. This again has two parts, corresponding to the contents of the two tests. The student can also go to final exam to increase grading or to be able to pass the exam, if the grading is smaller than 5. The best grading is the final grading.

Therefore, the grading will be:

$$\text{Grading}=(P1 \times 0.25)+(P2 \times 0.25)+(T1 \times 0.15) + (T2 \times 0.15) + (E \times 0.1)+(D \times 0.1)$$

If the grading is smaller than 5, the grading will be

$$\text{Grading}=(TF1 \times 0.4)+(TF2 \times 0.4)+ (E \times 0.1) +(D \times 0.1)$$

where TF_i is the exam they repeated, which can be any of the two or both. For the exam not repeated, TF_i=Ti.

For exemption students grading will be:

$$\text{Grading}=(T1 \times 0.40) + (T2 \times 0.40) + (Pra \times 0.2)$$

If they do not arrive to 3 over 10 in the first Test or second Test, this would be substituted (TS) by a final test. Equally if the grading is smaller than 5. Then, the grading will be

$$\text{Grading}=(TS1 \times 0.40) + (TS2 \times 0.40) + (Pra \times 0.2)$$

where TS₁ and TS₂ is the test that the student has to substitute because the grading of that test is smaller than 3 (if not TS_i=Ti). If simply the student has not reached a 5, the student can choose among TS₁, TS₂ or choose both of them.



10. Assessment

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.

2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	30	
Seminar Theory	30	
Lecture Practice	30	
Laboratory Practical	30	
Computer Practice	30	
Field Practice	30	



1. Code: 36102 **Name:** Open Quantum Systems and Thermodynamics II

2. Credits: 3,00 **--Lecture:** 1,50 **--Practice:** 1,50 **Type of Course:** Elective

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 2-Elective Courses and Externships

Subject: 8-Elective Courses and Externships

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Garcia March, Miguel Angel

Departament: APPLIED MATHEMATICS

4. References

5. Course outline

Course objectives

Open Quantum Systems is a subject that studies quantum systems interacting with an external environment. Unlike closed quantum systems, which evolve unitarily and are isolated from the outside world, open quantum systems account for decoherence, dissipation, and irreversible processes due to this interaction. Open quantum systems bridge idealized quantum mechanics and real-world systems by incorporating interaction with the environment. The subject is essential for understanding realistic quantum technologies, decoherence, and thermodynamic behavior in quantum contexts. The objectives are the following: 1) Make practical the formalism of open quantum systems, with several examples; 2) study the case of continuous variable, which is often absent in the studies of quantum technologies, and nevertheless the most common situation in nature; Study quantum Brownian motion; 3) Study the most deep formalism underlying open quantum systems: quantum trajectories and unravelings; 4) use the previous formalism for practical applications, like quantum Montecarlo methods; 5) Connect with Thermodynamics and Information Theory. The particular goal of this course is to arrive at the most profound understanding of quantum mechanics which may only be complemented via quantum field theory and related developments.

Contextualization of the course

Standard quantum mechanics typically assumes closed, isolated systems that evolve unitarily. But in reality, no system is truly isolated: interactions with an external environment (heat bath, vacuum fluctuations, measurement devices) are unavoidable. These interactions lead to decoherence, dissipation, and noise, necessitating a new formalism beyond Schrödinger's equation. Secondly, the open quantum systems approach helps explain how classical behavior emerges from quantum systems (decoherence). Moreover, it provides a framework for understanding real quantum technologies and quantum information theory. In modern physics and quantum technologies: a) it is essential for understanding and mitigating decoherence in quantum computers and sensors; b) it is central to modeling open quantum dynamics in condensed matter systems, atomic physics, and optomechanics; 3) it plays a role for the analysis of quantum feedback, control, time in quantum mechanics. It is crucial for a theory of measurement; and objectivity. Particularly for the theory of measurement and the emergence of objectivity for many observers of the same reality, the theory of quantum trajectories is very important. Also for the realistic modeling of quantum technologies, in particular, quantum computers.

6. Recommended prior knowledge

(36092) Quantum Photonics

(36093) Quantum computing and programming

(36094) Classical and Quantum Information Theory

(36095) Open Quantum Systems And Thermodynamics I

Knowledge of Advanced quantum mechanics, Statistical mechanics and thermodynamics (Ensembles - microcanonical, canonical, etc. -, Entropy, temperature, and equilibrium, irreversibility, partition functions and thermal states) would be useful. Also Linear Algebra (Vector spaces, inner products, Matrices, eigenvalues, eigenvectors, Tensor products, Unitary and Hermitian operators, Diagonalization and spectral decomposition); Other useful mathematical tools: Ordinary and partial differential equations, Fourier/Laplace transforms, complex variable, Probability theory and generally calculus. Also numerical methods and programming in python, or particularly with library QUTIP. Quantum optics.



7. Results

UPV-Generic student outcomes

(1) Social and environmental commitment

- Activities carried out to achieve the student outcome

Presentations in class of a short bibliographic search, small essay, work on some scientific paper, or calculation of a simple system.

- Assessment criteria

Evaluation time effort, originality, interest shown, understanding of complex concepts from the subjects and its application, and way of presenting, interaction with colleagues during questions made by whole class.

Learning Outcomes

RA1.1 - Assessing the ethical consequences of the decisions to be made in a specific situation, considering the impact on society and responsibility in professional practice.

(3) Teamwork and leadership

- Activities carried out to achieve the student outcome

Small exercises done in class during teaching in groups of two.

- Assessment criteria

Questions from professor to explain to which conclusions the team has arrived. Collaboration of both students, politeness, respect for each other ideas will be very valued. Working in a team is very important for research, and it's crucial to be respectful.

Learning Outcomes

RA3.3 - Collaborating proactively in the carrying out of work, setting goals and meeting objectives.

8. Syllabus

- Applications to Real-World Systems and typical models
 - Detailed derivation of the quantum optical master equation
 - Two-Level System: decay to general environments
 - Resonance fluorescence
 - Quantum Harmonic Oscillator in a Thermal Environment: the damped harmonic oscillator
 - Non-selective, continuous measurements: the quantum zeno effect
 - Quantum Brownian Motion
 - Caldeira-Leggett model and Spin-Boson Model
 - Practical session: Jaynes-Cummings-like model in the ultrastrong coupling regime
- Numerical and Simulation Tools: stochastic processes in Hilbert space
 - Probability distributions on Hilbert space
 - Stochastic dynamics in Hilbert space
 - Numerical solutions of master equations using Python (and QuTiP). The stochastic simulation method
 - Simulate quantum trajectories and quantum jump methods
 - Practical session: Correlation functions
- Extension of quantum thermodynamics and Information Theory
 - Entropy production, quantum thermodynamic laws, and fluctuation theorems.
 - Connection to quantum information theory, noise models and error correction.
 - Practical session: Evolution and quantum statistics of a quantum parameter amplifier
- Research Skills
 - Read critically research literature and reproduce results
 - Practical session: Quantum Monte-Carlo Trajectories

9. Teaching and Learning Methodologies

Computer sessions are the practical sessions.

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	4,00	--	2,50	--	--	1,00	1,00	8,50	12,00	20,50
2	4,00	--	2,50	--	--	1,00	1,00	8,50	12,00	20,50
3	4,00	--	2,50	--	--	1,50	1,00	9,00	12,00	21,00
4	3,00	--	2,50	--	--	1,50	1,00	8,00	12,00	20,00



9. Teaching and Learning Methodologies

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
TOTAL HOURS	15,00	--	10,00	--	--	5,00	4,00	34,00	48,00	82,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

Num. Acts Weight (%)

(05) Academic work	2	50
(15) Practical laboratory/field/computing/classroom test	1	10
(14) Written test	2	30
(11) Observation	1	10

- The written exams will be two tests. Each for a 15% of the final grade.
- The projects are divided in two parts, each for a 25% of the final grade. The projects serve also to evaluate the practical sessions, as it should include programming with qutip.
- Then, the ordinary acts are (each partial) a test (15%) and first part of project (25%).
- If the grading is smaller than 5, the student has to do a final exam. This will have two parts, corresponding to the contents of the two test exams. The first part corresponds to the first partial grading (and substitutes first part of project and first test, that is 25%+15%=40%) and second part corresponds to the second partial grading (and substitutes second part of project and second test, that is 25%+15%=40%). The student can choose to attend the first of second part to increase the grading or to be able to pass the subject, if the grading is smaller than 5. The best grading is the final grading.

In the case of students with exemption, the distribution will be:

- 2 test exams (40%+40% of the final grading). If the student does not pass, there will be a final exam for each of the test exams.
- One exam to evaluate the practical sessions with qutip (20% final grading). This exam cannot be repeated, nor does it have minimal grading.

For every test exam, if the grading is smaller than 3 over 10, the student must attend the corresponding final exam. This again has two parts, corresponding to the contents of the two tests. The student can also go to final exam to increase grading or to be able to pass the exam, if the grading is smaller than 5. The best grading is the final grading.

Therefore, the grading will be:

$$\text{Grading}=(P1 \times 0.25)+(P2 \times 0.25)+(T1 \times 0.15) + (T2 \times 0.15) + (E \times 0.1)+(D \times 0.1)$$

If the grading is smaller than 5, the grading will be

$$\text{Grading}=(TF1 \times 0.4)+(TF2 \times 0.4)+ (E \times 0.1) +(D \times 0.1)$$

where TFi is the exam they repeated, which can be any of the two or both. For the exam not repeated, TFi=Ti.

For exemption students grading will be:

$$\text{Grading}=(T1 \times 0.40) + (T2 \times 0.40) + (Pra \times 0.2)$$

If they do not arrive to 3 over 10 in the first Test or second Test, this would be substituted (TS) by a final test. Equally if the grading is smaller than 5. Then, the grading will be

$$\text{Grading}=(TS1 \times 0.40) + (TS2 \times 0.40) + (Pra \times 0.2)$$

where TS1 and TS2 is the test that the student has to substitute because the grading of that test is smaller than 3 (if not TSi=Ti). If simply the student has not reached a 5, the student can choose among TS1, TS2 or choose both of them.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.
2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.



10. Assessment

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	50	
Seminar Theory	50	
Lecture Practice	50	
Laboratory Practical	50	
Computer Practice	50	
Field Practice	50	



1. Code: 36096 **Name:** Quantum communications

2. Credits: 3,00 **--Lecture:** 2,00 **--Practice:** 1,00 **Type of Course:** Compulsory

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 1-Compulsory Training

Subject: 6-Quantum Communications

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Corral González, Juan Luis

Departament: COMMUNICATIONS

4. References

Quantum Communications
Quantum optics : an introduction

Cariolaro, Gianfranco.
Fox, Mark.

5. Course outline

Course objectives

This course discusses the general fundamentals of optical telecommunications systems and the difference between classical and quantum communications systems. The fundamentals of classical optical communications are introduced as a necessary prologue for quantum optical communications. The concept of optimal quantum decision is developed, expressing the results with the language of telecommunications, where the quantum decision is applied to the receiver. The general formulation of quantum communication systems is also developed, where the transmitter prepares and launches the information in a quantum channel and the receiver extracts the information by applying quantum decision rules. The subject has a strong focus on the description of the actual implementation of quantum communications system, from the individual component description up to the system point of view. Applications like Quantum-key-distribution (QKD), quantum teleportation or quantum networks are covered in the course.

Contextualization of the course

Classical optical communications are intrinsically related to quantum mechanics with the laser being one of the most successful applications of this theory. However, when talking about quantum communications we are moving a step further trying to use quantum technologies to improve the security of the transmission of information or even sharing quantum states between different sites. Photons are the preferred particle for the majority of applications of quantum communications so optical quantum communications will be the core of this subject, both in a theoretical and applied approach.

6. Recommended prior knowledge

(36092) Quantum Photonics

(36094) Classical and Quantum Information Theory

7. Results

Fundamental results

RF5(GE) Design secure and reliable quantum communications systems in the context of current telecommunication network infrastructures.

Learning Outcomes

RA13 - Apply the theoretical foundation of quantum communication systems to evaluate the performance of systems with coherent modulations.

RA14 - Analyze the feasibility of quantum communications in the context of current infrastructures in optical communication networks, both terrestrial, aerial, and satellite-based.

RA15 - Establish the secure and reliable distribution of information in systems with massive interconnection between nodes.

UPV-Generic student outcomes

(2) Innovation and creativity

- Activities carried out to achieve the student outcome
Evaluation of quantum communication scenarios
- Assessment criteria

Along the course, different problems will be presented as exercises to find the best solution according to the specifications of the components and the system performance.

Learning Outcomes



7. Results

UPV-Generic student outcomes

RA2.3 - Critically and constructively evaluating the advantages and opportunities of different solutions to the same problem.

(3) Teamwork and leadership

- Activities carried out to achieve the student outcome

TBD

- Assessment criteria

TBD

Learning Outcomes

RA3.1 - Functioning effectively in a team whose members jointly provide leadership and create a collaborative and inclusive environment in the organisation and coordination of work.

RA3.3 - Collaborating proactively in the carrying out of work, setting goals and meeting objectives.

8. Syllabus

1. Classical Optical Communications
 1. A telecommunication system (classical/quantum)
 2. Scenarios of classical optical communications: optical fiber and free space optics
 3. Poisson processes
2. Quantum Optical Communications
 1. Quantum Mechanics for Communications
 2. Modulation and Detection
3. Optical Components for Quantum Communications
 1. Sources and detectors
 2. Passive components
 3. Quantum Repeaters
4. Quantum Communications Systems
 1. Quantum Key Distribution
 2. Quantum Teleportation
 3. Quantum Networks

9. Teaching and Learning Methodologies

Two sessions will take place in a laboratory.

P1: Practical photon counting and quantum regime (2,5 h)

P2: Quantum decision on QAM modulations (2,5 h)

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	4,00	--	1,00	0,00	--	--	0,00	5,00	10,00	15,00
2	6,00	--	--	2,50	--	--	2,00	10,50	12,00	22,50
3	4,00	--	2,00	0,00	--	--	0,00	6,00	10,00	16,00
4	6,00	--	2,00	2,50	--	--	2,00	12,50	15,00	27,50
TOTAL HOURS	20,00	--	5,00	5,00	--	--	4,00	34,00	47,00	81,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

(15) Practical laboratory/field/computing/classroom test

(14) Written test

Num. Acts Weight (%)

2 20

2 80



10. Assessment

One written exam will take place after units 1 & 2 with a weight of 40% of the course grade. A second written exam at the end of units 3 & 4 will cover 40% of the grade.

The two lab sessions will be assessed during the sessions with a combined weight of 20%.

Both written exams could be retaken at the official date fixed by the ETSIT. Students who had already passed the subject with the previous exams are allowed to retake any of the two written exams in order to improve their qualification. These students are required to send an email to the course lecturers communicating their decision at least 72 hours in advance. Their final qualification will correspond to the best grade obtained.

The students excused from the obligation to attend classes will be assessed at the official date. Their exam will consist of one written test covering the units 1 to 4 (80% of the final qualification) and a practical test covering the lab sessions (20%).

In the final grade, having obtained a good result in the midterm exams may be positively recognized through an improvement in the grade. Besides, to grant distinctions, having obtained an excellent result in the midterm exams will preferably be valued.

In the event that a student commits fraud during the performance of an evaluation act, this act will be graded with a zero, with no possibility to retake it. In addition, the student will be referred to a single final exam, which may be oral, in which the remaining percentage will be evaluated (discounting the act in which fraud has been committed) until completing the total grade for the subject.

If there are indications about the use of AI or other not allowed materials during an exam or lab session, the affected student will be summoned to give a brief oral defense of what they have written in the exam or lab results.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.

2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	0	
Seminar Theory	0	
Lecture Practice	0	
Laboratory Practical	0	
Computer Practice	0	
Field Practice	0	



1. Code: 36093 **Name:** Quantum computing and programming

2. Credits: 6,00 **--Lecture:** 3,80 **--Practice:** 2,20 **Type of Course:** Compulsory

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 1-Compulsory Training

Subject: 3-Quantum Computing

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: García Almudéver, Carmen

Departament: COMPUTER ENGINEERING

4. References

5. Course outline

Course objectives

This course focuses on the fundamentals of quantum computing with the aim of understanding this new computational paradigm and being able to analyze and implement quantum algorithms on specific quantum hardware and simulation platforms making use of the available programming frameworks. After emphasizing the difference between classical and quantum computing and the advantages it can provide, the students will learn the basic concepts of quantum computing that encompasses quantum bits (qubits), measurement, superposition, entanglement, quantum gates and quantum circuits. In addition, some of the most popular quantum algorithms and protocols will be discussed. An overview on the development of quantum computers from a full-stack perspective including qubit implementation technologies, quantum instruction set, and related microarchitecture and compilers will be also provided. The students will also learn about the main challenges of developing future large-scale fault-tolerant quantum computers that requires the integration of quantum error correction and modular architectures.

Contextualization of the course

The field of quantum computing has experienced a remarkable progress in the last years becoming a tangible reality. Current quantum computers, also known as noisy intermediate-scale quantum (NISQ) devices, already integrate tens to hundreds of qubits and have been made available to users through the cloud. These systems are progressively transitioning to the so-called fault-tolerant application-scale quantum (FASQ) era, in which large-scale and fault-tolerant quantum computing machines are expected to provide the promised computational power. A quantum computer will not only be capable of solving relevant problems intractable by current classical computers, but it also represents a paradigm shift in the way how computing is performed.

Huge advances have recently been made in this field such as the several experimental demonstrations of quantum computational advantage or the implementation of fault-tolerant protocols for achieving a reliable computation. Furthermore, quantum processors are rapidly increasing their qubit counts (the number of qubits on a chip), especially in quantum computing systems based on superconducting circuits, trapped ions and neutral atoms, which already surpass the 1000-qubit barrier. There is still a long way to go and the challenges are diverse, but the future is promising and exciting.

6. Recommended prior knowledge

No prior knowledge is required, but knowledge of linear algebra and Python is recommendable.



7. Results

Fundamental results

RF3(GE) Programming algorithms on quantum computers for applications of practical interest.

UPV-Generic student outcomes

(1) Social and environmental commitment

- Activities carried out to achieve the student outcome

Identification of the potential problems that quantum computers might be able to solve and their impact on science/technology, society and environment.

- Assessment criteria

Section included in the final project.

Learning Outcomes

RA1.1 - Assessing the ethical consequences of the decisions to be made in a specific situation, considering the impact on society and responsibility in professional practice.

RA1.2 - Make informed judgments considering the impact of solutions, in the field of the discipline, in global, economic, social and environmental contexts.

(3) Teamwork and leadership

- Activities carried out to achieve the student outcome

Realisation of a project on a specific quantum computing and programming topic in groups.

- Assessment criteria

Observation during the project development and discussion sessions.

Learning Outcomes

RA3.4 - Helping find solutions to challenges or projects, showing empathy and assertiveness when sharing ideas, reflections and arguments within collaborative work.

8. Syllabus

1. From classical to quantum computing
 1. What is different in quantum computing?
 2. Nowadays quantum computing systems: progress and prospects
 3. Complexity theory and quantum complexity
 4. Complex numbers and linear algebra for quantum computation
2. Quantum bits, quantum gates and quantum circuits.
 1. From bits to qubits: superposition and measurement
 2. Visualizing single-qubit states: the Bloch Sphere
 3. Single-qubit gates
 4. Multi-qubit systems: entanglement
 5. Quantum circuits
 6. Quantum teleportation
3. Quantum algorithms and protocols.
 1. Classical computations on a quantum computer
 2. Quantum parallelism and interference
 3. The Deutsch and the Deutsch-Jozsa algorithms
 4. The Grover's algorithm
 5. The Quantum Fourier Transform
4. Quantum computing architectures
 1. Full-stack quantum computing systems: functional layers
 2. Quantum programming frameworks
 3. Quantum processor constraints
 4. Compilation of quantum circuits
5. Quantum error correction
 1. The basics of error correction
 2. From classical to quantum error correction
 3. Quantum error correction codes
 4. The surface code
 5. Quantum error mitigation techniques



9. Teaching and Learning Methodologies

Labs (6 sessions of 2h each)

1. Introduction to Python and Qiskit
2. Qubits: superposition and measurement
3. Quantum circuits
4. Quantum algorithms
5. Executing quantum circuits on NISQ processors
6. Quantum Error Correction

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	5,00	--	1,00	--	--	2,00	0,00	8,00	14,00	22,00
2	8,00	--	1,00	--	--	4,00	2,00	15,00	21,00	36,00
3	7,00	--	2,00	--	--	2,00	0,00	11,00	20,00	31,00
4	9,00	--	3,00	--	--	2,00	0,00	14,00	25,50	39,50
5	9,00	--	3,00	--	--	2,00	0,00	14,00	22,50	36,50
TOTAL HOURS	38,00	--	10,00	--	--	12,00	2,00	62,00	103,00	165,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

	<u>Num. Acts</u>	<u>Weight (%)</u>
(05) Academic work	1	60
(15) Practical laboratory/field/computing/classroom test	1	30
(11) Observation	1	10

The evaluation of the course consists of:

- 1 open-answer written exam (30%, Units 1 and 2). There will also be an open-answer resit. The minimum grade required for compensation and therefore passing the course is 3,5.
- 1 final project that will include a state-of-the-art/research part and a more practical (programming) part based on the labs (60%). Students will be given the chance to resubmit the project (resit) if the average final grade is <5. There is no minimum mark required for the final project.
- 10% of the grade is based on observation, meaning development of the lab work and participation and engagement in the class and project discussions.

Therefore, the final average grade will be calculated as follows:

$$\text{Final_grade} = 0,3 * \text{written exam} + 0,6 * \text{final project} + 0,1 * \text{observation}$$

Students who do not attend the lectures because they have a class exemption ('dispensa') will be evaluated based on the grades obtained in the exam and the final project. In this case, the final grade will be: $0,34 * \text{written exam} + 0,65 * \text{final project}$

Students will be given the opportunity to retake the exam/final project to improve their grade. In this case, the average final grade will be calculated based on the mark obtained in the resit, regardless of whether it is higher or lower than the grade previously obtained.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The



10. Assessment

final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.

2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	20	
Seminar Theory	20	
Lecture Practice	0	
Laboratory Practical	0	
Computer Practice	0	
Field Practice	0	



1. Code: 36101 **Name:** Quantum Computing for Industrial and Economic Sectors

2. Credits: 3,00 **--Lecture:** 1,50 **--Practice:** 1,50 **Type of Course:** Elective

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 2-Elective Courses and Externships

Subject: 8-Elective Courses and Externships

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Guerola Navarro, Vicente

Departament: BUSINESS ORGANISATION

4. References

Introduction to Quantum Computing for Business.

The potential impact of quantum computers on society

Quantum Computing: Between Hope and Hype, Shtetl-Optimized, 22 September

Defining the quantum workforce landscape: a review of global quantum education initiatives

Variational quantum circuits for machine learning. An application for the detection of weak signals

Groenland, Koen.

de Wolf, Ronald

Scott Aaronson (2024)

Kaur, Maninder| Venegas-Gomez, Araceli

Griol Barres, Israel| Cebrián Ferriols, Antonio

José| Millet Roig, José| Milla, Sergio| Mansoori,

Yashar

5. Course outline

Course objectives

Develop the skills to create a business model in the field of quantum computing, in the photonics sector, with a clear entrepreneurial, technological, and dynamic focus.

Contextualization of the course

This subject offers an introductory and interdisciplinary overview of how quantum computing can transform industrial and economic sectors, with a special emphasis on photonics. This subject explores fundamental industry principles based on quantum computing and their applicability to complex problems in optimization, simulation, and data analysis. This subject analyzes how photonics and quantum technology integrate to develop innovative solutions in areas such as telecommunications and energy, preparing students to face the challenges of an emerging technological economy.

6. Recommended prior knowledge

No need for previous knowledge.

7. Results

UPV-Generic student outcomes

(1) Social and environmental commitment

- Activities carried out to achieve the student outcome

During the theoretical and practical sessions, the content and activities will be directly linked to the applicability of new technologies in achieving the SDGs of the UN's 2030 Agenda.

- Assessment criteria

Through practical sessions and class participation.

Learning Outcomes

RA1.1 - Assessing the ethical consequences of the decisions to be made in a specific situation, considering the impact on society and responsibility in professional practice.

(3) Teamwork and leadership

- Activities carried out to achieve the student outcome

The practical sessions will be developed through group work.

- Assessment criteria

Through the results of group work in the classroom and participation in sessions.

Learning Outcomes

RA3.2 - Identifying roles and skills to operate in multidisciplinary teams with different professional profiles.



8. Syllabus

1. UD1: Contextualization: business and quantum and photonic computing
 1. Business context of the photonics sector
 2. Business context of the quantum computing sector
2. UD2: Business Models (MN)
 1. Definition and components. Value proposition. Canvas. Added value and competitive advantage
 2. MN Patterns
 3. Tools for MN design
 4. MN strategy and business competitiveness
3. UD3: Marketing
 1. Marketing strategies and business metrics
 2. Communication of entrepreneurial projects
4. UD4: Legal framework around intellectual property, data protection and security
 1. Legal framework.

9. Teaching and Learning Methodologies

Practical sessions schedule:

PL1 - Case study of a real university-born tech startup. (2 hours)

PL2 - Design thinking + Pestel + SWOT (2 hours)

PL3 - Market segmentation (2 hours)

PL4 - Validating business models (2 hours)

PL5 - Multidimensional marketing strategy (2 hours)

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	0,00	--	4,00	2,00	--	--	1,00	7,00	5,00	12,00
2	7,00	--	1,00	6,00	--	--	2,00	16,00	30,00	46,00
3	6,00	--	--	2,00	--	--	1,00	9,00	15,00	24,00
4	2,00	--	--	0,00	--	--	0,00	2,00	2,00	4,00
TOTAL HOURS	15,00	--	5,00	10,00	--	--	4,00	34,00	52,00	86,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

	<u>Num. Acts</u>	<u>Weight (%)</u>
(05) Academic work	1	10
(15) Practical laboratory/field/computing/classroom test	1	40
(14) Written test	1	40
(11) Observation	1	10

At the beginning of the course, the criteria and tools that will be applied to the assessments are established with the students. All assessments are graded with a score between 0 and 10 points. An assessment is considered passed if it obtains a score equal to or greater than 4 points. Assessments must be submitted on the scheduled date.

Academic Assignments (10%): Participation and attitude in classroom activities are assessed overall, along with Observation (10%). For students with a DISPENSA (Exempt), tasks punctuality will be checked and assessed. This block will be retaken through an academic assignment exam during the course's final exam session. Student behavior and participation in theory, practical, and seminar sessions will be assessed, with a total weighting of 20% of the final grade. The instructor may request the completion of a document/project to evaluate the effectiveness of attendance and participation in classroom activities.

Regarding the written exam (40%): the objective tests consist of one multiple-choice exam that can be completed on paper or



10. Assessment

electronically via PoliformaT. The open-response written tests consist of one exam, which must be answered in a limited space and will be administered at the same time as the multiple-choice exam. Both tests will be administered together on the day scheduled in the official program calendar. Students with a DISPENSA (Exempt) may take the test in the manner and date agreed upon with the instructor.

The practical laboratory test (40%) includes the assessment of the laboratory practices carried out throughout the semester, both in person and individually and online for students with a DISPENSA (whose latter may form groups). These practices can be recovered by taking a practical exam during the final exam session for the course.

To obtain a Matrícula de Honor (Honours Degree), the student must have obtained a numerical grade of 9. The evaluation will be at the discretion of the professor based on attendance, participation, and classroom attitude. The professor may request arguments and supporting documentation from the student for their application as a candidate for Matrícula de Honor (Honours Degree).

If the student passes the course and takes the make-up exam, the final grade will be the most recent obtained (whether higher or lower).

Intentional fraud in an assessment procedure will result in a grade of zero, without prejudice to any disciplinary measures that may result. If a student has lost the right to be assessed in an assessment procedure due to the application of the Academic Integrity Regulations (NIA), they will not be eligible for continuous assessment and must take a final exam worth 100% of the course grade. This test may be oral, and the final grade will be the one obtained in it.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.
2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	30	
Seminar Theory	0	
Lecture Practice	0	
Laboratory Practical	30	
Computer Practice	0	
Field Practice	0	



1. Code: 36103 **Name:** Quantum Cryptography

2. Credits: 3,00 **--Lecture:** 1,50 **--Practice:** 1,50 **Type of Course:** Elective

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 2-Elective Courses and Externships

Subject: 8-Elective Courses and Externships

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Garcia March, Miguel Angel

Departament: APPLIED MATHEMATICS

4. References

Introduction to Quantum Cryptography
A course in number theory and cryptography
Codificación de la información
Understanding cryptography : a textbook for students and practitioners
Cryptography
Quantum computation and quantum information
Cryptography for secure encryption
Introduction to classical and quantum computing
Dancing with qubits : how quantum computing works and how it may change the world

Vidick, Thomas
Koblitz, Neal
Munuera Gómez, Juan
Paar, Christof
Rubinstein-Salzedo, Simon.
Nielsen, Michael A.
Underwood, Robert G.
Wong, Thomas G.
Sutor, Robert S.

5. Course outline

Course objectives

The importance of Quantum Cryptography comes from how it changes the fundamentals of secure communication. Instead of relying on mathematical difficulty (like traditional encryption), it uses the laws of Quantum Mechanics to guarantee security. The objectives are: 1) To offer an accessible introduction to quantum cryptography and develop some practical skills; 2) To introduce several important applications such as quantum key distribution, quantum one-time pad and quantum money; These require more advanced quantum technologies; 3) study other methods with less requirements on technologies, delegated quantum computation and device independent protocols; 4) To offer simple examples nevertheless relevant to quantum cryptography; 5) To present the challenges of cryptographic security; 6) Evaluate limitations and challenges; Evaluate physical implementations; 6) Discuss future directions; 7) When possible, compare with classical cryptography.

Contextualization of the course

Cryptography is the study of methods of secure communication between two parties. A central aspect of this is confidentiality in the sense that eavesdropping is not possible, that is, no unauthorized person has a chance to intercept the transmitted information. Another aspect is authentication, i.e. a secure way of verifying that the person on the other end of the line is the one who he or she is pretending to be. These security demands raise the problem of key distribution, i.e. the generation of a key which is shared by the sender and recipient while being sure that nobody else can know it. This problem is frequently addressed by using an asymmetric key scheme, involving a public and a private key, where the public key is used for encryption, the private key for decryption at the receiving end, and the private key can not be computed from the public key. The latter assertion is ultimately based on computational assumptions, for example the assumption that factoring large numbers is a computationally very intensive task. In such a computationally secure system, the private key could theoretically be calculated from the public key by factoring a large number, which however would require a very long time even when using the most advanced computers. However, this may change with the advent of quantum computers, which should be able to solve such factoring tasks in much shorter times, or if an efficient mathematical algorithm for factoring numbers were to be invented.

Quantum cryptography uses quantum mechanical properties to perform cryptographic tasks and obtaining perfect (unconditional) security. It usually involves quantum key distribution, i.e. a system for key distribution which exploits quantum mechanics to prohibit with perfect security that anyone can intercept or break the secret key. The importance of Quantum Cryptography comes from how it changes the fundamentals of secure communication. Instead of relying on mathematical difficulty (like traditional encryption), it uses the laws of Quantum Mechanics to guarantee security. It is important because the security is rooted in physics, not assumptions: Classical cryptography (like RSA) depends on problems being hard to solve. But advances in computing, especially quantum computing, could break them. Quantum cryptography uses principles like Heisenberg Uncertainty Principle, meaning that observing a quantum system changes it. So, any attempt to eavesdrop is automatically detectable, to some extent. Also it will offer protection against future threats from quantum computers.



6. Recommended prior knowledge

- (36092) Quantum Photonics
- (36093) Quantum computing and programming
- (36094) Classical and Quantum Information Theory
- (36095) Open Quantum Systems And Thermodynamics I
- (36096) Quantum communications

7. Results

UPV-Generic student outcomes

(2) Innovation and creativity

- Activities carried out to achieve the student outcome

Information search concerning emerging trends, advances in knowledge, technological advances and/or ongoing challenges in quantum cryptography. The goal is to identify gaps, future research directions, or potential real-world applications.

- Assessment criteria

The student will be required to make a report or a short presentation (within one of the proposed activities) describing the obtained information. This report or presentation will be evaluated based on depth and relevance of the research, clarity in communication and the ability to synthesize the information.

Learning Outcomes

RA2.1 - Identifying new challenges, projects or opportunities for improvement in the field of the discipline aligned with future trends and advances.

(3) Teamwork and leadership

- Activities carried out to achieve the student outcome

One of the assessment events consists of a project developed as a group work.

- Assessment criteria

The project will be evaluated taking into account the level of collaboration among group members, as well as the individual contribution of each member.

Learning Outcomes

RA3.4 - Helping find solutions to challenges or projects, showing empathy and assertiveness when sharing ideas, reflections and arguments within collaborative work.

8. Syllabus

1. Quantum tools and a the one-time pad
 1. General introduction and revision of concepts
 2. Probability Notation, density matrices and measurements
 3. Secure Message Transmission and first protocol, the one-time pad
 4. Practical session: the one-time pad
2. Quantum Money
 1. First scheme for quantum money
 2. Wiesner's Quantum Money and quantum channels
 3. Attacks on Wiesner's scheme
 4. Practical session: quantum money
3. More concepts on quantum mechanics
 1. Entanglement and the monogamy of entanglement
 2. Quantifying Information
 3. Privacy amplification and randomness extractors
 4. Practical session: concepts on quantum information for cryptography
4. Distributing Keys
 1. Honest and dishonest agents
 2. Secure key distribution and information reconciliation
 3. Quantum key distribution protocols
 4. Practical session: QKD Protocols
5. Quantum Cryptography using untrusted devices
 1. Device-Independent Quantum Key Distribution and its security
 2. Testing EPR pairs
 3. Practical session: DIQKD protocols



8. Syllabus

6. Further topics

1. Quantum cryptography beyond key distribution
2. Physical assumptions, implementations and their security
3. Delegated computation

9. Teaching and Learning Methodologies

The hours of computer practice are distributed as follows:

Practice 1: the one-time pad (2 hours)

Practice 2: quantum money (2 hours)

Practice 3: concepts on quantum information for cryptography (2 hours)

Practice 4: QKD Protocols (2 hours)

Practice 5: DIQKD Protocolss (2 hours)

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	3,00	--	1,00	--	--	2,00	1,00	7,00	10,00	17,00
2	3,00	--	1,00	--	--	2,00	1,00	7,00	10,00	17,00
3	3,00	--	0,75	--	--	2,00	1,00	6,75	10,00	16,75
4	2,00	--	0,75	--	--	2,00	1,00	5,75	10,00	15,75
5	2,00	--	0,75	--	--	1,00	1,00	4,75	5,00	9,75
6	2,00	--	0,75	--	--	1,00	1,00	4,75	5,00	9,75
TOTAL HOURS	15,00	--	5,00	--	--	10,00	6,00	36,00	50,00	86,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

	<u>Num. Acts</u>	<u>Weight (%)</u>
(05) Academic work	1	50
(15) Practical laboratory/field/computing/classroom test	1	10
(14) Written test	1	30
(11) Observation	2	10

Student assessment will be continuous and based on 5 evaluation components.

- Two of these components (C1 and C2) correspond to the submission of academic assignments: two short portfolios in which students will solve problems proposed by the instructor related to the course content (each weighted at 5%).

- One component (C3) is the development of a project that may consist of:

* a more thorough and in-depth development of one of the topics covered during the course, or

* the exploration of a topic related to classical or quantum cryptography that expands upon the course contents, or

* the development of the mathematical justification of some results that will be used throughout the course but will not

be fully covered due to time constraints.

This project may be required to be presented orally for evaluation.

- One component (C4) will consist of a written test or exam with questions concerning the contents of the course.

- The last component (C5) will consist of a test concerning skills acquired in the use of the computer software to solve questions related with the contents of the course.



10. Assessment

The final grade will be computed as follows:

$$\text{Final_Grade} = 0.05 \cdot C1 + 0.05 \cdot C2 + 0.5 \cdot C3 + 0.3 \cdot C4 + 0.1 \cdot C5$$

A student will be considered to have passed the course if $C4 \geq 4$ and $\text{Final_Grade} \geq 5$.

If a student does not achieve these conditions, he/she will have the opportunity to take a final recovery exam, which accounts for 80% of the course grade. If N is the grade obtained in this exam, then the final grade for the course will be calculated as follows:

$$\text{Final_Grade} = 0.05 \cdot C1 + 0.05 \cdot C2 + 0.8 \cdot N + 0.1 \cdot C5,$$

and the student will pass the course if $\text{Final_Grade} \geq 5$.

Students who have been granted exemption from attending classes will be assessed using the same evaluation criteria as the rest of the students.

Final grade will be 4 if minimal gradings for all parts are ≥ 1 , and 3 of any < 1 . Students who has passed the normal evaluation can apply to final exam only to upgrade grading. This should be communicated 3 days before exam. New grading substitutes previous, even though it may be smaller.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.
2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	30	
Seminar Theory	30	
Computer Practice	30	



1. Code: 36098 **Name:** Quantum Machine Learning

2. Credits: 3,00 **--Lecture:** 2,00 **--Practice:** 1,00 **Type of Course:** Elective

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 2-Elective Courses and Externships

Subject: 8-Elective Courses and Externships

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Naranjo Ornedo, Valeriana

Departament: COMMUNICATIONS

4. References

Introduction to machine learning with Python : a guide for data scientists
A practical guide to quantum machine learning and quantum optimisation :
hands-on primer to quantum computing - from qubits to quantum machine
learning and beyond

Müller, Andreas C.
Combarro, Elias F.

5. Course outline

Course objectives

This course offers a comprehensive programme that merges two areas : machine learning and quantum computing. Starting with an in-depth study of machine learning, students acquire essential knowledge in supervised classifiers, neural networks, and optimisation techniques such as gradient descent. Subsequently, the programme dives into the field of variational quantum algorithms, addressing both their theoretical foundations and practical applications.

The exploration continues with a detailed analysis of Quantum Support Vector Machines and Quantum Kernel Methods, providing a unique perspective on the interplay between classical and quantum methods. Students will also investigate Quantum Neural Networks.

The programme concludes with a review of recent advances in the field, preparing students to contribute to the development and application of these emerging technologies. This comprehensive approach ensures a thorough understanding of both the fundamental principles and practical applications in the rapidly developing field of quantum computing and machine learning.

Contextualization of the course

This course is part of the first year of the master's program. The student has a strong background in mathematics, programming, and quantum computing (also studied during the same year). In this course, the student will explore machine learning methods in depth, as well as their quantum versions.

6. Recommended prior knowledge

(36093) Quantum computing and programming

Programming in Python
Algebra



7. Results

UPV-Generic student outcomes

(1) Social and environmental commitment

- Activities carried out to achieve the student outcome

Test about ethics in artificial intelligence

- Assessment criteria

Task in poliforma-T: results of the test

Learning Outcomes

RA1.3 - Demonstrating awareness of respect for diversity and the principles of universal accessibility and design for all people.

(3) Teamwork and leadership

- Activities carried out to achieve the student outcome

Final work of the course in teams

- Assessment criteria

oral assessment with a rubric

Learning Outcomes

RA3.1 - Functioning effectively in a team whose members jointly provide leadership and create a collaborative and inclusive environment in the organisation and coordination of work.

8. Syllabus

- Machine learning Fundamentals
 - PL1. Machine learning applications
- Variational quantum algorithms
 - PL2. Definition and training of variational quantum circuits
- Quantum Support Vector Machines and Kernel Methods
- Quantum Neural Networks

9. Teaching and Learning Methodologies

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	12,00	--	3,00	--	--	2,00	1,00	18,00	19,00	37,00
2	5,00	--	1,00	--	--	3,00	1,00	10,00	13,00	23,00
3	2,00	--	0,50	--	--	--	1,00	3,50	6,00	9,50
4	1,00	--	0,50	--	--	0,00	1,00	2,50	12,00	14,50
TOTAL HOURS	20,00	--	5,00	--	--	5,00	4,00	34,00	50,00	84,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

	<u>Num. Acts</u>	<u>Weight (%)</u>
(05) Academic work	1	40
(14) Written test	2	50
(11) Observation	2	10

The assessment will consist of:

-Two written tests to evaluate theoretical and practical concepts, one in the middle of the semester and another at the end. Each will account for 25% of the final grade.

-A final project for the course: 20% for the code and 20% for the oral defense.

-Participation and performance in lab sessions: 10%, based on observation during the laboratory work.

The student will be allowed to retake each of the two midterm tests separately. The final project may also be resubmitted, following the improvements indicated by the professors. The lab participation grade, however, cannot be recovered.



10. Assessment

If the student considers it appropriate to take the final recovery exams established in the teaching guide to improve the final grade, the final grade will be the maximum of the grade obtained in this exam and the corresponding grade of the ordinary assessment.

The conditions for this exam will be published in the exam announcement. Students who wish to sit the exam must notify the lecturer responsible for the subject by post at least 3 calendar days in advance. The final mark of the course, for all students, will be the maximum between the ordinary evaluation and the recovery.

The evaluation of students with dispensation will be the same as for the rest of the students. In the case of the 10% of the laboratory practices, it will be prorated among the rest of the evaluations, 5% more for the final work, and 5% for the written exams.

If a student commits academic fraud during an assessment, that assessment will be graded as a zero, with no opportunity for a recovery grade. In addition, the student will be required to take a single final exam, which may be oral, to assess the remaining portion of the course(excluding the assessment in which the fraud occurred) until the final grade for the course is determined.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.

2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	100	
Seminar Theory	100	
Lecture Practice	100	
Laboratory Practical	100	
Computer Practice	100	
Field Practice	100	



1. Code: 36099 **Name:** Quantum Metrology

2. Credits: 3,00 **--Lecture:** 2,00 **--Practice:** 1,00 **Type of Course:** Elective

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 2-Elective Courses and Externships

Subject: 8-Elective Courses and Externships

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Gómez Hernández, Víctor Jesús

Departament: APPLIED PHYSICS

4. References

Introduction to Quantum Metrology : Quantum Standards and Instrumentation
Quantum metrology : foundation of units and measurements.

Nawrocki, Waldemar.
Goebel, Ernst O.

5. Course outline

Course objectives

Quantum metrology is a field of theoretical and experimental study of high-resolution and high-accuracy methods for the measurement of physical quantities based on quantum mechanics, particularly using quantum entanglement. In this subject the following goals are pursued:

To introduce the theory and practical realizations of quantum standards of units

To define the quantum Hall effect and the resistance standard

To define the Josephson effect and the voltage standard

To define the single electron tunneling and the current standard

To describe the working principles of scanning probe microscopes

Expose students to industrial and market perspectives, highlighting current applications, emerging technologies, and career opportunities in the quantum-technology ecosystem.

Contextualization of the course

Quantum metrology is a field of theoretical and experimental study of high-resolution and high-accuracy methods for the measurement of physical quantities based on quantum mechanics, particularly using quantum entanglement. Without equivalent in classical mechanics, quantum entanglement of particles or other quantum systems is an unusual phenomenon in which the state of a system can be determined better than the state of its parts. Attempts are made to use new measurement strategies and physical systems in order to attain measurement accuracy never achieved so far. Quantum metrology only started to develop in the latter half of the twentieth century, following the discovery of phenomena of fundamental importance to this field, such as the Josephson effect, the quantum Hall effect, or the tunneling of elementary particles (electrons, Cooper pairs) through a potential barrier. Using new important physical advances, quantum metrology also contributes to progress in physics. In 1964;2012, the Nobel Prize was awarded for important discoveries such as the Josephson effect (Josephson, 1973), the quantum Hall effect (von Klitzing, 1985), and the scanning tunneling microscope (Röhrer and Binnig, 1986). Thus, scientific achievements in quantum metrology or relevant to this field are considered very important for science in general.

The program includes laboratory sessions. A research project is also included, aimed at translating the studied concepts into practical cases drawn from recent research or technological developments.

6. Recommended prior knowledge

(36091) Solid State Physics



7. Results

UPV-Generic student outcomes

(2) Innovation and creativity

- Activities carried out to achieve the student outcome

As part of the course, students will engage in a comparative analysis activity focused on quantum measurement techniques. Each student (or group) will select a specific physical quantity (e.g., time, magnetic field, temperature, or phase) and analyze at least two different quantum metrology approaches to measure it (e.g., interferometry vs. atomic clocks for time; SQUIDs vs. NV centers for magnetic fields).

The task will require:

Technical Review

Reviewing the principles, theoretical background, and implementation of each method, supported by scientific literature.

Comparative Evaluation

Critically assessing the advantages, limitations, and application contexts of each technique. This includes analyzing precision, noise resilience, experimental complexity, cost, and scalability.

Proposal of Context-Based Recommendations

Justifying, based on the analysis, which technique is better suited for different practical scenarios (e.g., field applications, fundamental research, industrial deployment).

- Assessment criteria

Deliverables include an oral presentation. This activity will develop the students' ability to assess alternative solutions to the same measurement problem and promote evidence-based decision-making, fostering a constructive and critical evaluation of scientific methods.

Learning Outcomes

RA2.3 - Critically and constructively evaluating the advantages and opportunities of different solutions to the same problem.

(5) Responsibility and decision-making

- Activities carried out to achieve the student outcome

With the previous activity both RA are going to be evaluated.

- Assessment criteria

Deliverables include a short report.

Learning Outcomes

RA5.2 - Develop and conduct practical or experimental work and research, interpreting data and drawing conclusions based on the principles of the discipline.

8. Syllabus

1. Quantum Hall Effect and the Resistance Standard
2. Superconductivity; Josephson effect and the Quantum Voltage Standards
3. Single electron tunneling; Quantum Standards of Electric Current; Scanning Probe Microscopies
4. Perspective on companies and market in this sector.
5. LAB1: Optomechanical Cavities
6. LAB2: Scanning Probe Microscopies
7. LAB3: Presentations and defense

9. Teaching and Learning Methodologies

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	4,00	--	1,00	0,00	--	--	1,00	6,00	12,00	18,00
2	6,00	--	2,00	0,00	--	--	1,00	9,00	15,00	24,00
3	6,00	--	2,00	--	--	--	1,00	9,00	15,00	24,00
4	4,00	--	--	--	--	--	1,00	5,00	4,00	9,00
5	--	--	--	2,00	--	--	--	2,00	2,00	4,00
6	--	--	--	2,00	--	--	--	2,00	2,00	4,00
7	--	--	--	1,00	--	--	--	1,00	2,00	3,00
TOTAL HOURS	20,00	--	5,00	5,00	--	--	4,00	34,00	52,00	86,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment.



9. Teaching and Learning Methodologies

CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

	<u>Num. Acts</u>	<u>Weight (%)</u>
(05) Academic work	1	30
(15) Practical laboratory/field/computing/classroom test	1	20
(14) Written test	1	40
(11) Observation	1	10

Assessment Criteria:

Academic Work: 30%

This includes the oral presentation of the research project, and/or peer evaluation.

Written Exam: 40%

Multiple choice exam covering theoretical and practical content (theory and classroom practice, plus lab-related questions).

Practical test: 20%

From short-answer or multiple-choice quizzes aimed at promoting continuous learning.

Observation: 10%

Based on the systematic collection of data during the lectures, execution of tasks...

In the event of failing the written exam and/or the practical test, both can be retaken within the period allotted for retaking exams.

Students who have passed the written exam and wish to retake it to improve their final grade may do so by specifying in advance that they wish to improve their grade.

IMPORTANT: The retake grade will be considered for the final grade, even if it is lower than the grade obtained in the exam taken throughout the course.

In the event of an exemption from attendance, the student will only have to complete the written exam for the evaluation of the subject. In that case, the written exam will be computed as the 100% of the final grade.

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.

2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	0	
Seminar Theory	0	
Lecture Practice	0	
Laboratory Practical	0	
Computer Practice	0	
Field Practice	0	



1. Code: 36092 **Name:** Quantum Photonics

2. Credits: 6,00 **--Lecture:** 3,80 **--Practice:** 2,20 **Type of Course:** Compulsory

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 1-Compulsory Training

Subject: 2-Quantum Photonics

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Capmany Francoy, José

Departament: COMMUNICATIONS

4. References

Introductory quantum optics

Gerry, Christopher C.

5. Course outline

Course objectives

This course provides an elementary introduction to the subject of quantum optics, the study of the quantum-mechanical nature of light and its interaction with matter. It is almost entirely concerned with the quantized electromagnetic field. Topics covered include single-mode field quantization in a cavity, quantization of multimode fields, quantum phase, coherent states, quasi-probability distribution in phase space, atom-field interactions, the Jaynes-Cummings model, quantum coherence theory, beam splitters and interferometers, nonclassical field states with squeezing etc., tests of local realism with entangled photons from downconversion, experimental realizations of cavity quantum electrodynamics, trapped ions, decoherence, and some applications to quantum information processing, particularly quantum cryptography.

Contextualization of the course

Quantum photonics provides the tools for the understanding of a broad set of concepts from other disciplines in the Master, including solid state physics, quantum communications and quantum computing.

6. Recommended prior knowledge

(36091) Solid State Physics

(36093) Quantum computing and programming

(36094) Classical and Quantum Information Theory

It is advisable that the student has completed courses on quantum mechanics and photonics.

7. Results

Fundamental results

RF2(GE) To formulate the quantum states of light, its interaction with matter and its applications.

Learning Outcomes

RA4 - Explain the quantum nature of light, as well as its temporal and spatial propagation.

RA5 - Develop technological solutions in the fields of information processing, computing, or communications based on the interaction of light with matter.

RA6 - Define the concepts of quantum polarization, quantum interference, and quantum coherence of light at different orders.

RA7 - Formalize and characterize the different quantum states of light in order to generate, transform, and detect these states using optical systems.

UPV-Generic student outcomes

(2) Innovation and creativity

- Activities carried out to achieve the student outcome

Application of quantum photonic principles to the basic understanding of quantum information systems

- Assessment criteria

Small project

Learning Outcomes

RA2.1 - Identifying new challenges, projects or opportunities for improvement in the field of the discipline aligned with



7. Results

UPV-Generic student outcomes

future trends and advances.

RA2.2 - Proposing creative solutions to satisfactorily meet the real needs and problems of society.

(5) Responsibility and decision-making

- Activities carried out to achieve the student outcome

Search for areas beyond those included in the course where the application of quantum photonics can be particularly useful

- Assessment criteria

Small project

Learning Outcomes

RA5.1 - Identify, formulate and solve complex problems autonomously, applying the principles of the discipline.

8. Syllabus

1. Field quantization
 1. Quantization of a single-mode field
 2. Quantum fluctuations of a single-mode field
 3. The quadrature operators for a single-mode field
 4. Quantization of multimode fields
 5. Introduction to thermal fields
 6. Vacuum fluctuations and zero-point energy
 7. The quantum phase
 8. Computer practice (2 hours)
2. Coherent states
 1. Eigenstates of the annihilation operator
 2. Displaced vacuum states
 3. Wavepackets and time evolution
 4. More properties of coherent states
 5. Phase space pictures of coherent states
 6. Density operators and phase space probability distributions
 7. Computer practice (2 hours)
3. Emission and absorption of radiation by atoms
 1. Atom-field interactions
 2. Interaction of an atom with a quantized field
 3. Interaction of an atom with a quantized field
 4. The Rabi model
 5. The Jaynes-Cummings model
 6. The dressed states
 7. Density operator approach
 8. Computer practice (2 hours)
4. Quantum coherence functions
 1. Classical coherence functions
 2. Quantum coherence functions
 3. Young's interference in quantum regime
 4. Higher order coherence functions
 5. Computer practice (2 hours)
5. Beamsplitters, interferometers and modulators
 1. Quantum mechanics of beamsplitters
 2. Interferometry with a single photon
 3. Interaction-free measurement



8. Syllabus

4. Interferometry with coherent states of light
5. The SU(2) formulation of beamsplitting and interferometry
6. The beamsplitter as a displacer
7. The phase modulator
8. Computer practice (2 hours)
6. Nonclassical light
 1. Quadrature squeezing
 2. Generation and detection of quadrature squeezed light
 3. Number squeezed states
 4. Photon antibunching
 5. Schrödinger cat states
 6. Two-mode squeezed vacuum states
 7. Computer practice (2 hours)

9. Teaching and Learning Methodologies

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	7,00	--	2,00	--	--	2,00	--	11,00	20,00	31,00
2	6,00	--	2,00	--	--	2,00	--	10,00	16,00	26,00
3	7,00	--	2,00	--	--	2,00	--	11,00	20,00	31,00
4	5,00	--	1,00	--	--	2,00	--	8,00	10,00	18,00
5	7,00	--	2,00	--	--	2,00	--	11,00	20,00	31,00
6	6,00	--	1,00	--	--	2,00	--	9,00	14,00	23,00
TOTAL HOURS	38,00	--	10,00	--	--	12,00	--	60,00	100,00	160,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

	<u>Num. Acts</u>	<u>Weight (%)</u>
(05) Academic work	1	30
(15) Practical laboratory/field/computing/classroom test	6	30
(14) Written test	1	40

1) Recovery and Reassessment Policy:

The following assessment components are recoverable, as their weight is equal to or greater than 30% of the final grade:

Academic work (30%)

Written test (40%)

Practical laboratory/field/computing/classroom test (30%)

Students who do not pass any of these components during the continuous assessment period will have the opportunity to retake them during the official resit period.

The resit activities will be designed to assess the same learning outcomes as the original activities:

The written test will be reassessed through a written exam.

The practical component will be reassessed through an equivalent practical test or assignment.

The academic work will be reassessed through the submission of a revised or alternative project.

Overall, 100% of the course assessment corresponding to components with weight $\geq 30\%$ is recoverable, thus exceeding the minimum requirement of 70%.

In all cases, the final grade for each recoverable component will be the highest of the two obtained marks (continuous assessment or resit).



10. Assessment

2) Improvement of grades

Students who have passed the course may choose to participate in the resit period in order to improve their grades in any of the recoverable components (academic work, written test, and practical test).

In such cases, the final grade for each component will be the highest obtained between the original assessment and the resit.

3) Assessment for Students with Attendance Waiver

Students who have been officially granted an attendance waiver will be assessed through alternative evaluation methods covering 100% of the course grade.

The assessment structure will be as follows:

Written test: 40%

Practical component: 30%

Academic work: 30%

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.

2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	15	
Seminar Theory	15	
Lecture Practice	15	
Laboratory Practical	15	
Computer Practice	15	
Field Practice	15	



1. Code: 36091 **Name:** Solid State Physics

2. Credits: 6,00 **--Lecture:** 3,80 **--Practice:** 2,20 **Type of Course:** Compulsory

Degree: 2345-Master's Degree in Quantum Information and Photonics

Module: 1-Compulsory Training

Subject: 1-Solid State Physics

University Center: SCHOOL OF TELECOMMUNICATIONS ENGINEERING

3. Coordinator: Pinilla Cienfuegos, Elena

Departament: APPLIED PHYSICS

4. References

The Oxford solid state basics
Solid State Physics

Simon, Steven H.
Ashcroft, Neil W. | Mermin, N. David | Rodriguez,
Sergio

5. Course outline

Course objectives

Solid State Physics provides an in-depth understanding of the physical principles governing the properties of solids, with a focus on crystalline materials. Topics include crystal structures, electronic band theory, lattice vibrations, semiconductors, and magnetic and optical properties of materials. Emphasis is placed on the quantum and statistical mechanics underlying solid-state phenomena, as well as their relevance to modern technologies such as microelectronics, photonics, and quantum devices.

Contextualization of the course

Solid State Physics is a key subject for students aiming to work in advanced areas like materials science, nanotechnology, quantum technologies, and electronic or photonic device engineering. A deep understanding of the behavior of solids at the atomic and electronic level is essential for designing and optimizing materials with specific electrical, thermal, optical, or magnetic properties. This subject connects fundamental physics concepts with real-world applications for advances in the development of technologies based on semiconductors, sensors, superconductors, and quantum materials. Understanding these concepts gives students the skills and scientific know-how they need to succeed in both research and cutting-edge tech industries.

6. Recommended prior knowledge

Students taking this subject are expected to have a background in undergraduate-level quantum mechanics, statistical physics, and electromagnetism. Familiarity with concepts such as wave functions, energy quantization, basic operator formalism, and statistical ensembles will be desirable for understanding the quantum and thermal properties of solids. Some background in crystallography, electronic structure of atoms, and Fourier analysis will also be helpful.

7. Results

Fundamental results

RF1(GE) Explain the nature of physical platforms as well as the structure and properties of solid materials used in quantum and photonic systems.

Learning Outcomes

RA1 - Describe the relationship between structure, bonding characteristics, and the mechanical, electronic, and optical properties of solids.

RA2 - Explain the thermal properties of solids based on the phenomena associated with atomic vibrations in the crystal lattice.

RA3 - Develop the quantum theory of electronic transport in solids and relate it to cooperative phenomena such as magnetism, superfluidity, and superconductivity.

UPV-Generic student outcomes

(4) Effective communication

- Activities carried out to achieve the student outcome

Students will work in small groups to explore a recent development or application in solid state physics. The group will prepare and deliver a oral seminar, making sure the explanation is accessible but technically accurate.

The presentation will include:

- An introduction to the core physics involved.
- A real-world application or current research highlight.



7. Results

UPV-Generic student outcomes

- A visual explanation (e.g., diagrams, animations, analogies).
- A short Q&A session to engage with the audience.

Each group will also submit a Collaborative Learning Report including:

- A description of how the group divided responsibilities and managed their time.
- The learning strategies used to understand the topic.
- How the team decided on the communication style and structure of the presentation.
- Reflections on teamwork, challenges, and lessons learned.
- Assessment criteria
 - Clarity and organization of the seminar.
 - Appropriate adaptation of content to the audience.
 - Use of visuals and analogies to support understanding.
 - Verbal and non-verbal communication during the presentation.
 - Ability to engage the audience and respond to questions effectively.

Learning Outcomes

RA4.3 - Communicate and argue effectively, adapting the organization of content and the use of language, verbal and nonverbal, to different situations and/or a range of audiences.

(5) Responsibility and decision-making

- Activities carried out to achieve the student outcome
Same activity described for RA 4.3
- Assessment criteria
 - Evidence of collaborative learning and knowledge acquisition.
 - Effective time management and division of roles.
 - Quality of self-reflection and identification of challenges in the report.
 - Initiative and critical thinking in selecting and presenting the topic.

Learning Outcomes

RA5.3 - Acquire and apply new knowledge as needed, using appropriate learning and time management strategies.

8. Syllabus

1. Crystalline structure
2. Lattice vibrations & Quantization of vibrations: phonons
3. Electrons in solids
4. Many-body quantum theory
5. Quantum theory of electronic transport
6. Magnetism & Superconductivity
7. Laboratory 1: Introduction to experimental techniques
8. Laboratory 2: Surface-Enhanced Raman Scattering (SERS) in Nanoparticle-on-Mirror Systems
9. Laboratory 3: Electrical characterization of semiconductors. Hall effect and RF
10. Laboratory 4: Microscopy ECCI, SEM Y EDS
11. Laboratory 5: Presentations

9. Teaching and Learning Methodologies

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
1	3,00	--	1,00	--	--	--	1,00	5,00	5,00	10,00
2	8,00	--	2,00	--	--	--	1,00	11,00	10,00	21,00
3	8,00	--	2,00	--	--	--	1,00	11,00	10,00	21,00
4	8,00	--	3,00	--	--	--	1,00	12,00	10,00	22,00
5	8,00	--	3,00	--	--	--	1,00	12,00	10,00	22,00
6	3,00	--	1,00	--	--	--	1,00	5,00	5,00	10,00
7	0,00	--	0,00	2,00	--	--	0,20	2,20	5,00	7,20
8	--	--	0,00	2,00	--	--	0,20	2,20	5,00	7,20
9	--	--	--	2,00	--	--	0,20	2,20	5,00	7,20



9. Teaching and Learning Methodologies

<u>DU</u>	<u>LE</u>	<u>SE</u>	<u>PS</u>	<u>LS</u>	<u>FW</u>	<u>CP</u>	<u>AA</u>	<u>CH</u>	<u>NCH</u>	<u>TOTAL HOURS</u>
10	--	--	--	2,00	--	--	0,20	2,20	5,00	7,20
11	--	--	--	2,00	--	--	2,20	4,20	25,00	29,20
TOTAL HOURS	38,00	--	12,00	10,00	--	--	9,00	69,00	95,00	164,00

UN: Unit. LE: Lecture. SE: Seminar. PS: Practical session. LS: Lab sessions. FW: Field work. CP: Computer-mediated practice. AA: Assessment. CH: Contact hours. NCH: Non contact hours.

10. Assessment

Outline

	<u>Num. Acts</u>	<u>Weight (%)</u>
(05) Academic work	1	30
(15) Practical laboratory/field/computing/classroom test	1	15
(14) Written test	2	50
(11) Observation	1	5

Academic Work: 30%

This includes the written research project and its oral presentation, and/or peer evaluation.

Written Exam: 50%

2 written exam covering theoretical and practical content (theory and classroom practice, plus lab-related questions). The theoretical content is a 40% and the practical content is a 10% of the total grade of each written exam.

Practical test: 15%

Short-answer or multiple-choice quizzes aimed at promoting continuous learning.

Observation 5%

Based on the systematic collection of data during the lectures, execution of tasks...

In the event of failing the written exams and/or the academic work, both can be retaken within the period allotted for retaking exams.

Students who have passed the written exam and wish to retake it to improve their final grade may do so by specifying in advance (at least three days in advance of the exam date) that they wish to improve their grade.

IMPORTANT: The retake grade will be considered for the final grade, even if it is lower than the grade obtained in the exam taken throughout the course.

If a student loses the right to be assessed in a given activity due to the application of the Academic Integrity Regulations (NIA UPV), they will no longer be eligible for continuous assessment. Instead, they must take a final exam, conducted in an oral format, which will account for 100% of the course grade.

In the event of an exemption from attendance, the student will only have to complete the written exam for the evaluation of the subject covering theoretical and practical content (theory and classroom practice, plus lab-related questions), questions about lab sessions will be included (only the theoretical part).

In the event of detection of alleged academic fraud in any assessment activity, this must be substantiated and documented through the corresponding academic integrity report.

As an immediate academic consequence, the affected assessment activity will be graded with a score of zero (0), without prejudice to the student's right to submit allegations and to lodge any applicable appeals.

In such case, the teacher responsible for the subject may replace the ordinary assessment system in its entirety with the following alternative assessment system:

1. The student will be required to complete a comprehensive assessment test, excluding the part affected by the incident. The final grade for the subject will be the result of the assessment weighted by the percentage corresponding to the content of this test. The part affected by the incident will retain a score of 0 and its original weighting in the final grade.

2. Said test may be oral in nature and must comply with the principles of objectivity and proportionality. If the alternative assessment system is not applied, the ordinary system set out in the course guide will be applied in full.

The application of these measures is independent, where applicable, of the possible initiation of disciplinary proceedings in accordance with current university regulations.

11. Absence threshold



11. Absence threshold

<u>Activity</u>	<u>Percentage</u>	<u>Observations</u>
Lecture Theory	0	
Seminar Theory	0	
Lecture Practice	0	
Laboratory Practical	0	
Computer Practice	0	
Field Practice	0	