Asignatura: Nanofotónica
Código: 30608
Centro: Facultad de Ciencias
Titulación: Máster Universitario en Física de la Materia Condensada y Nanotecnología
Nivel: Máster
Tipo: optativa
Nº de créditos: 4 ECTS

ASIGNATURA / COURSE TITLE

Nanofotónica / Nanophotonics

1.1. Código / Course number

30608

1.2. Materia / Content area

Temas avanzados de física de la materia condensada y de nanotecnología/ Advanced topics on Condensed Matter Physics and Nanotechnology

1.3. Tipo / Course type

Formación optativa / Elective subject

1.4. Nivel / Course level

Máster / Master (second cycle)

1.5. Curso / Year

1º/1st

1.6. Semestre / Semester

2º trimestre / 2nd trimester

1.7. Número de créditos / Credit allotment

4 ECTS

1.8. Requisitos previos / Prerequisites

Es muy recomendable tener conocimientos previos de electromagnetismo, óptica, mecánica cuántica, física de la materia condensada y cálculo numérico /
It is highly advisable to have some previous knowledge of electromagnetism, optics, quantum mechanics, condensed matter physics, and numerical calculus.

Asimismo, los alumnos deben disponer de un nivel de inglés adecuado que permita seguir las clases y leer la bibliografía de consulta / Students must have a suitable level of English to follow the lectures and read the references.

1.9. Requisitos mínimos de asistencia a las sesiones presenciales / **Minimum attendance requirement**

La asistencia es obligatoria al menos en un 90% / Attendance at a minimum of 90% of in-class sessions is mandatory.

1.10. Datos del equipo docente / **Faculty data**

Docente / Lecturer:
Juan Antonio Porto Ortega (coordinador)
Departamento / Department of: Física Teórica de la Materia Condensada
Facultad / Faculty: Ciencias
Despacho – Módulo/ Office – Module: 511 - 05
Teléfono / Phone: +34 91 497 8628
Correo electrónico/Email: ja.porto@uam.es
Página web / Web page: http://www.uam.es/ja.porto
Horario de atención al alumnado/Office hours: Contact the lecturer for a tutorial.

Other professors from the same department lecturing in this course:
Esteban Moreno Soriano, Jorge Bravo Abad, Francisco José García Vidal, and Carlos Tejedor de Paz.

1.11. Objetivos del curso / **Course objectives**

El objetivo de este curso consiste en que los estudiantes adquieran un conocimiento básico sobre Nanofotónica, esto es, el estudio de la propagación, confinamiento e interacción con la materia de campos electromagnéticos en la escalas de la longitud de onda y sub-longitud de onda. También se pretende que los estudiantes se familiaricen con algunos de los métodos numéricos usados en Nanofotónica. Al acabar el curso, se espera que los estudiantes conozcan las tendencias actuales en varios campos de investigación de la Nanofotónica, como es el caso de la Plasmónica, los cristales fotónicos o la óptica de campo cercano. /
The aim of this course is to provide the students with a basic knowledge of Nanophotonics, i.e., the field devoted to the study of electromagnetic field propagation, confinement, and interaction with matter at the wavelength and sub-wavelength scales. It is also intended to familiarize the students with some of the numerical methods used in Nanophotonics. By the end of the course, the students are expected to be informed about recent trends in several research areas of Nanophotonics, such as Plasmonics, photonic crystals, near-field optics, and metamaterials.

1.12. Contenidos del programa / **Course contents**

1. **Basic concepts of classical electrodynamics.** Macroscopic Maxwell equations. Spectral representation of time-dependent fields. Time-harmonic fields. Constitutive relations. Boundary conditions. Wave equations. Dyadic Green's function. Poynting theorem. Angular spectrum representation of optical fields. Plane waves and evanescent waves. Guided and confined fields. Scattering theory of electromagnetic waves.

2. **Focusing of optical fields and near-field optics.** Field propagators. Paraxial approximation. Propagation and focusing of optical fields. The resolution limit. Principles of confocal microscopy. Scanning near-field optical microscopy (SNOM). Types of SNOM. Applications of SNOM. Related techniques.

3. **Photonic crystals.** Definition and examples. Symmetry and Maxwell equations. Physical mechanism underlying the photonic gap. Band structures and photonic Bloch modes. Microcavities and waveguides. Circuits. Surface modes. Other phenomena based on the photonic crystal concept: extraordinary optical transmission and beaming of light, negative refraction, supercollimation.

4. **Plasmonics.** Optical properties of noble metals. Surface plasmon polaritons at planar interfaces. Surfaces plasmon polaritons on structured metallic surfaces. Localized surface plasmons. Enhanced transmission of radiation through subwavelength apertures and apertures arrays. Beaming of light. Guiding and focusing of surface plasmon polaritons. "Spoof" surface plasmons.

5. **Metamaterials and transformation optics.** Metamaterial concept. Negative-index materials. Negative refraction. The "perfect lens" proposal. Imaging with metamaterials. Transformation optics. Optical cloaking.

6. **Non-linear photonics and laser action at the sub-wavelength scale.** Introduction to nonlinear optics and lasing action with emphasis on fundamentals for optics and photonics research. Nonlinear effects including self phase modulation, nonlinear wave propagation, and solitons. Spontaneous and stimulated emission (lasers). Gas, solid-state and semiconductor lasers. Examples of current research topics in nanophotonics: solitons in graphene, efficient terahertz generation via nonlinear frequency mixing, and photonic-crystal and plasmonic lasers.

7. **Quantum optics.** Condensed matter systems as components for quantum optics. Cavity quantum electrodynamics. Dynamics: master equation and quantum regression theorem. Photon-photon correlation spectroscopy and quantum tomography.

8. **Numerical methods in nanophotonics.** Finite-difference time-domain (FDTD) method. Finite-element method (FEM). Multiple multipole (MMP) method. Modal expansion methods.

1.13. Referencias de consulta / Course bibliography

- L. Novotny and B. Hecht, *Principles of Nano-optics* (Cambridge University Press, 2nd edition, 2012).
- J.D. Jackson, *Classical Electrodynamics* (Wiley, 3rd edition, 1999).
- S.A. Maier, *Plasmonics: Fundamentals and Applications* (Springer, 1st edition, 2007).
- J.D. Joannopoulos, S.G. Johnson, J.N. Winn, and R.D. Meade, *Photonic Crystals: Molding the Flow of Light* (Princeton University Press, 2nd edition, 2008).
- M.O. Scully and M.S. Zubairy, *Quantum Optics* (Cambridge University Press, Cambridge, 1997).

2. Métodos docentes / Teaching methodology

- Clases presenciales teóricas / Standard lectures.
- Seminarios realizados por investigadores invitados / Seminars by invited speakers.
- Clases prácticas de resolución de problemas / Practical lectures for solving problems.
- Tutorías a petición del alumno. / Tutorials upon student request.

3. Tiempo de trabajo del estudiante / Student workload

		Nº de horas	Porcentaje
Presencial	Clases teóricas Clases prácticas Seminarios	35 h (35%)	37 h = 37%
	Presentaciones orales de estudiantes	2 h (2 %)	
No presencial	Estudio semanal	40 h (40%)	63 h = 63%
	Preparación de trabajos	23 h (23%)	
Carga total de horas de trabajo: 25 horas x 4 ECTS		**100 h**	

		Number of hours	Percentage
Face-to-face tuition	Lectures Problem-solving sessions Seminars	35 h (35%)	37 h = 37%
	Oral presentations by students	2 h (2 %)	
Independent study	Independent study of course contents	40 h (40%)	63 h = 63%
	Final project	23 h (23%)	
Total student workload: 25 hours x 4 ECTS		**100 h**	

4. Métodos de evaluación y porcentaje en la calificación final / Evaluation procedures and weight of components in the final grade

La calificación final será la obtenida mediante la siguiente fórmula:
(a) Trabajo de fin de curso (resumen escrito y presentación oral) = 70%,
(b) Evaluación continua y resolución de hojas de problemas = 30%. /

The final mark will be the result of the following formula:
(a) Final work (written report and oral presentation) = 70%,
(b) Continuous assessment and solving of problem sets = 30%.

5. Cronograma* / Course calendar

Semana Week	Contenido Contents	Horas presenciales Contact hours	Horas no presenciales Independent study time
1 - 2	Temas 1 / **Unit 1**	7	8
3 - 4	Tema 2 / **Unit 2**	7	8
5	Tema 3 / **Unit 3**	3.5	4
6	Tema 4/ **Unit 4**	3.5	4
7	Tema 5 / **Unit 5**	3.5	4
8	Tema 6/ **Unit 6**	3.5	4
9	Tema 7 / **Unit 7**	3.5	4
10	Tema 8 / **Unit 8**	3.5	4
11	Presentaciones finales / **Final oral presentations**	2	23

*Este cronograma tiene carácter orientativo.

*This course calendar might be liable to some changes.