

Master program

"Physics for Optics and Nanosciences"

Detailed course contents for the M1 academic year 2011-2012

(April 2011)

Mandatory courses are in red. Elective courses are in black.

SEMESTER 1

2 elective courses must be chosen in the first period (Sept. – Dec.) and 2 elective courses must be chosen in the second period (Jan. – Apr.) for a minimum of 12 ECTS.

Courses	Professor in charge	ECTS	Course location ^(*)
Quantum optics : Lasers	A. Aspect	4	X
Quantum physics of electrons in solids	A. Georges	4	X
Atomic and molecular physics	N. Kebâili	4	X
Labworks	L. Jacubowicz	3	IOGS
French language (2 semesters)		3	X
Sub-Total		18	
4 Elective courses		12	
Total		30	

1st period (Sept. – Dec.)			
Fundamentals in Biology	G. Peyroche	3	ENSC
Introduction to nanophotonics	E. Deleporte	5	ENSC
Introduction to microfluidics	O. Français	3	ENSC
Wave optics	A. Dubois	4	IOGS
Materials design	T. Gacoin	4	X
Lasers and applications	M. Joffre	4	X
Magnetism and superconductivity	K. van der Beek	4	X
2nd period (Jan. – Apr.)			
Nonlinear optics	N. Dubreuil	3	IOGS
Semiconductor and laser diodes	G. Lucas-Leclin	3	IOGS
Guided and coupled waves	J.M. Jonathan	3	IOGS
Nanomaterials and electronics	B. Drévillon	4	X
Optoelectronics	E. Rosencher	4	X
Functional thin films and active surfaces	T. Gacoin	4	X

SEMESTER 2

Courses	Professor in charge	ECTS	Course location ^(*)
Statistical physics	J.J. Greffet	3	IOGS
Electrodynamics	C. Krafft	3	IOGS
Experimental project	A. de Martino	4	X
Sub-Total		10	
Project in research Laboratory	F. Hache	20	
Total		30	

(*) X stands for "Ecole Polytechnique", IOGS for "Institut d'Optique – graduate school", ENSC for "Ecole Normale Supérieure de Cachan". X and IOGS are located in the same campus. ENSC (about 20 km north) can be easily reached with public transportation (RER B).

Research project

Students are expected to work on a research project for at least 11 weeks, in a laboratory of the site (Ecole Polytechnique, Institut d'Optique – Graduate School, Ecole Normale Supérieure de Cachan, Université Paris 11). Students are expected to write a report and to perform an oral defense. The evaluation of the project will take into account the report, the defense as well as the evaluation of the project supervisor.

Validation of the M1

Examinations are performed at the end of each course. Litteral marks are given: A (excellent), B (very good), C (good), D (poor), E (fail). A course and its corresponding ECTS is directly awarded by the jury when the mark is higher or equal to C.

A course and its corresponding ECTS may also be awarded by the jury if the mark is D, through compensation within a given semester by a A or a B in another course.

A semester is validated when 30 ECTS have been obtained. The M1 is validated as a consequence of the validation of the two semesters.

In case of failure at a course exam, the jury can decide a second examination session.

Main professor: Alain Aspect

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: *Quantum Optics : Lasers*

Objectives : *Quantum optics describes light and its interaction with matter. This course is devoted to laser physics, a flourishing field where a distinction between basic physics and engineering is irrelevant.*

Outline

Lect	PSS
18 h	18 h

- ◆ - *Transition probabilities.*
- ◆ - *Interaction between atoms and radiation.*
- ◆ - *Lasers : principle and general properties.*
- ◆ - *CW lasers.*
- ◆ - *Pulsed lasers.*
- ◆ - *Elements of statistical optics : application to coherence and laser linewidth.*
- ◆ - *Applications of lasers.*
- ◆ - *Laser cooling and trapping of atoms.*

Teachers: *Prof. A. Aspect, Institut d'Optique, Prof. F. Bretenaker, Lab. Aimé Cotton, Orsay*

Prerequisites: *Quantum mechanics, classical electrodynamics*

Course given in common with: *Ecole Polytechnique's « Ingénieur » Program*

Evaluation: **3h written exam**

Total number of hours : 36h
Total number of credits (ECTS) : 4

Main professor: Antoine Georges

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: ***Quantum physics of electrons in solids***

Objectives : *This is an introductory course to condensed matter physics, an inter-disciplinary field which has implications for physics, materials science, chemistry and biology. Materials with novel functionalities are a key to technological progress (e.g: semiconductors, magnetic memories, superconductors, polymers and composite materials, carbon nanotubes, etc...). Using the theoretical foundations of quantum mechanics and statistical physics, the course aims at understanding how electronic properties of materials at a macroscopic level results from their microscopic aspects at the atomic or molecular level. The presentation balances theoretical, experimental and technological viewpoints.*

Outline

Lect	PSS
18 h	18 h

- ◆ *Quantum mechanics of electrons in crystalline solids, energy bands.*
- ◆ *Metals, insulators and semiconductors.*
- ◆ *Some spectroscopic techniques (e.g. : X-ray and neutron diffraction, scanning tunneling microscopy, photoemission).*
- ◆ *Introduction to transport phenomena : Drude, Boltzmann.*
- ◆ *Nano-conductors and quantum regimes of transport.*
- ◆ *Introduction to magnetism and/or superconductivity.*

Teachers: *Prof. A. Georges, Ecole Polytechnique, Prof. S. Biermann, Ecole Polytechnique*

Prerequisites: *Quantum mechanics*

Course given in common with: *Ecole Polytechnique's « Ingénieur » Program*

Evaluation: ***3h written exam***

Total number of hours : 36h
Total number of credits (ECTS) : 4

Main professor: Nouari Kebaili

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: *Atomic and molecular physics*

Objectives : *The physics of atoms and molecules which constitutes the subject matter of this course rests on a long history of discoveries, both experimental and theoretical. Far from giving a complete account of the historical development, this introductory course aims to give an understanding of both theoretical foundations and key steps which have occurred in this field. As a direct application of quantum mechanics it includes materials on basic atomic and molecular physics with discussion on structure, spectra and interaction with electric and magnetic field.*

Outline

Lect PSS

18 h 18 h

- ◆ *Introduction :*
 - *Key steps on electrons, photons and atoms studies*
 - *Elements of quantum mechanics*
- ◆ *One-electron atoms :*
 - *Schrodinger equation for one-electron atoms*
 - *Special hydrogenic systems*
 - *Interaction with electromagnetic radiation*
 - *Fine structure and hyperfine structure*
 - *Interaction with external fields*
- ◆ *Many-electron atoms ;*
 - *Central field approximation*
 - *The periodic system of the elements*
 - *Corrections to the central field approximation : L-S and j-j coupling*
 - *Interaction with electromagnetic radiation and with static fields*
- ◆ *Molecular structure*
 - *The Born-Oppenheimer approximation*
 - *Molecular orbital theory*
 - *The calculation of electronic structure*
 - *Molecular rotations and vibrations*
 - *Molecular electronic transitions*

Teachers: *Dr N. Kébaïli, Lab Aimé Cotton, Université Paris XI*

Prerequisite: *Quantum Mechanics, Classical analytical mechanics*

Evaluation: *3h written exam*

Total number of hours : 36h

Total number of credits (ECTS) : 4

Main professor: Peyroche Gérard

Teaching form:
lectures (Lect) and problem solving sessions (PSS).

Mention: ***Fundamentals of Biology***

Objectives :

The aim of this course is to give to non-biologist students the basic concepts of modern biology which permit full understanding of the relevant biological questions in Nanosciences topics.

Outline

	Lect	PSS	LW
<i>Macromolecular structures (Lect, 6h)</i>	26 h	4 h	0 h
<i>Fundamentals of enzymology (Lect, 4h)</i>			
<i>Introduction to the world of living beings (Lect, 2h)</i>			
<i>Structure and main properties of plasmatic membranes (Lect, 2h)</i>			
<i>Structure and main properties of mitochondria (Lect, 2h)</i>			
<i>Transcription in bacteria (Lect, 2h)</i>			
<i>Messenger mRNA biogenesis in eukaryotes (Lect, 2h)</i>			
<i>Translation in bacteria and in eukaryotes (Lect, 2h)</i>			
<i>DNA replication in bacteria and in eukaryotes (Lect, 2h)</i>			
<i>DNA topology (Lect, 2h)</i>			
<i>Random mutagenesis and its application to the study of a protein function (PPS, 4h)</i>			

Teachers: Dr B. Sclavi (LBPA / ENS Cachan), Pr C. Auclair[#], Pr. U.Hazan[#], Dr M.H. Kryszke[#], Dr P. Rialland-Le Fèvre[#], Dr G. Peyroche[#]. Some lectures are given by selected PhD students (all have obtained agregation).
[#] Departement of biology, ENS Cachan.

Prerequisites : none.

Course given in common with: *master Erasmus mundus MONABIPHOT.*

Maximum number of students: 25

Evaluation: *3h written exam on lectures and problems.*

Total number of hours : 30 h
Total number of credits (ECTS) : 3

Main professor: Isabelle LEDOUX-RAK and Emmanuelle DELEPORTE

Teaching form: Lect

Mention: ***Introduction to Nanophotonics : Physics, Materials, Characterization and Manipulation***

Objectives : *This course, which is devoted to Nanophotonics, covers both theoretical and practical aspects of the physical description, the fabrication and the characterization techniques of nano-objects and nanostructures for photonics.*

Outline	Lect	PSS	LW
<i>Physics at the nanometric scale and applications to photonics</i>	16		
1. Definitions and basics: state densities, bandgap structures, excitons			
2. Quantum confinement			
a. 2D quantum confinement. Illustrations in semiconductor quantum wells			
b. 1D quantum confinement. Illustrations in semiconductor quantum wires and carbon nanotubes			
c. 0D quantum confinement. Illustrations in self-assembled InAs/GaAs quantum dots and CdSe soft chemistry grown quantum dots.	16		
3. Interaction between nano-objects and light.			
a. Absorption coefficient			
b. Emission properties			
c. Description of several optical experiments			
d. Analysis of the optical spectra	16		
<i>Instrumentation in nanophotonics and applications</i>			
1. Structural microscopy techniques: electron microscopy (EM), atomic force microscopy (AFM), tunneling microscopy			
2. Optical microscopy: luminescence, nonlinear effects (two-photon fluorescence, second and third harmonic generation, surface enhanced Raman scattering)			
3. Nano-objects manipulation: AFM, optical tweezers			
4. Application to Biology			
<i>Nanostructures for photonics: description and fabrication methods</i>			
1. "Top-down" elaboration techniques of nanostructures : photolithography, etching techniques. Electron and ion beam lithography.			
2. STM and AFM techniques for the manipulation of nano-objects			
3. Nanoparticles: preparation and functionalization : metallic colloids, semi-conductors, inorganic oxides, latex			
3. Bulk insertion and macroscopic organization			
a. solubilization: role of tensioactive molecules			
b. insertion in amorphous matrices			
c. self-organization			

Teachers: *Emmanuelle Deleporte, University Professor, LPQM, Institut d'Alembert, ENS Cachan
Isabelle Ledoux-Rak, University Professor, LPQM, Institut d'Alembert, ENS Cachan
Sophie Brasselet, CNRS Research scientist, Institut Fresnel, Marseille University*

Prerequisites: *Elements of statistical and quantum physics, and of material science*

Course given by : *Erasmus Mundus "MONABIPHOT" Master Course coordinated by ENS Cachan*

Maximum number of students: 35

Evaluation: **4 h written exam**

Total number of hours : 50 h
Total number of credits (ECTS) : 5

Main professor: Olivier Français

Teaching form:
lectures (Lect), labworks (LW)

Mention: ***Introduction to microfluidics: fundamentals and applications***

Objectives : *The aim of these lectures is to introduce fluid mechanics at the micro-scale to students, from fundamentals to applications. The recent development of Lab-on-a-chip requires a better understanding of flow properties at the microscale (to transport or mix chemical and biochemical substances) as well as finding technological solutions for traditional 'macro-functionalities' like valves, pumps, mixers ...*

Outline

Lect	PSS/LW
15 h	15 h

Theoretical teaching

- ◆ *Introduction : basic fluid mechanics; physics at the micro-scale*
- ◆ *Micro-hydrodynamic : hypothesis at the micro-scale, slippery effect at smooth surfaces, hydrodynamic résistance, hydrodynamic capacity, bottle neck effect, interfacial phenomena, diphasic flows.*
- ◆ *Diffusion, mixing and particle sorting in Microsystems.*
- ◆ *Electrohydrodynamic : electrokinetics, electroosmosis, electrophoresis, dielectrophoresis.*
- ◆ *Heat transfer and transport in Microsystems.*
- ◆ *Lab-on-a-chip examples.*

Practical training

- ◆ *Manufacturing of a micro-device*
- ◆ *Flow visualisation and study in the manufactured micro-device*

- ◆ *Dimensionnal analysis, scaling laws.*
- ◆ *Hydrodynamic resistance and slippery effect*
- ◆ *Electrohydrodynamic (electroosmosis, electrowetting)*
- ◆ *Heat transfer*

Teachers: *Dr O. Français (ENS-Cachan)*

Prerequisites: *Solid-state physics, optics, ...*

Course given in common with: *Master Erasmus Mundus "Monabiphot"*

Evaluation: ***Paper analysis***

Total number of hours : 30 h

Total number of credits (ECTS) : 3

Main professor: Arnaud Dubois, Nathalie Westbrook

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: *Wave Optics*

Objectives : *The bases of the wave optics theory are established from the electromagnetic theory of light. Diffraction, spatial filtering and image formation are treated under Fourier analysis. Interferometry is studied taking into account the influence of spatial and temporal coherence. The propagation of light in anisotropic media is also presented.*

Outline

Lect	PSS
33 h	9 h

Introduction to electromagnetic theory of light

- Maxwell's equations
- The wave equation
- Intensity and power
- Dielectric media

Introduction to wave optics

- Complex representation of monochromatic waves
- Helmholtz equation
- Elementary waves
- Fresnel approximation
- Reflection, refraction
- Transmission of optical components

Interferometry

- Interference of two waves
- Temporal coherence, spatial coherence
- Fourier-transform spectroscopy

Fourier Optics

- Plane wave decomposition, spatial frequencies
- Transfer function of free space
- Impulse-response function of free space
- Optical Fourier transform in the far field, optical Fourier transform using a lens
- Fraunhofer diffraction and Fresnel diffraction
- Spatial filtering
- Image formation with coherent and incoherent illumination
- Impulse-response function and transfer function of an optical system

Teachers: Prof. A. Dubois, Prof. N. Westbrook (IOGS)

Course given in common with: M1 Erasmus Mundus OpSciTech

Evaluation: 3h written exam

Total number of hours : 42 h

Total number of credits (ECTS) : 4

Main professor: Silke Biemann, Thierry Gacoin

Teaching form:
lectures (Lect)

Mention: ***Materials Design***

Objectives : *Exploring specific materials properties is a prerequisite for technological development and the design of new devices. The goal of this course is to initiate the students in the design process which leads from the intrinsic properties of matter to the specifically shaped material, used within a functional device..*

Outline

- Chemical and structural properties of materials; description of the main techniques of production and shaping of materials Lect
36 h

- Electronic properties of materials, in particular concerning transport, magnetism and optical properties

- Use of functional materials in the design of devices; notion of active or intelligent materials (materials whose properties can be controlled by an external stimulus, such as an electric or magnetic field, heat, mechanical pressure ...). Examples include electrochromic or electroluminescent materials, metals with shape memory, electro-rheological fluids ...).

During the course, the students will work on a personal project, whose goal it is to study on an explicit example of a given material the whole chain fabrication, properties, function. This work may include an experimental part to be completed in one of the labs of the Ecole Polytechnique.

Teachers: Prof. S. Biemann, Prof. T. Gacoin (CNRS)

Course given in common with: *Ecole Polytechnique's « Ingénieur » Program*

Evaluation: **3h written exam**

Total number of hours : 36h

Total number of credits (ECTS) : 4

Main professor: Manuel Joffre, Antonello de Martino

Teaching form:
lectures (Lect), labworks (LW)

Mention: ***Lasers and Applications***

Objectives : *This course introduces several important aspects of laser physics and nonlinear optics such as beam propagation and ultrashort pulse dispersion. The first part of the course consists of the introduction of a theoretical background on nonlinear optics and the physics of ultrashort laser pulses. The lectures will be constantly illustrated with numerical simulations performed by the students themselves. The second part will apply this background to experiments which will take place either in the center for experimental work or in research laboratories (LOA, LOB, ...) using femtosecond lasers. The experiments will include femtosecond pulse characterization and pulse shaping, harmonic generation in the extreme ultra-violet, attosecond holography and laser micro-machining..*

Teachers: *Prof. M. Joffre, Prof. A. de Martino (CNRS)*

Course given in common with: *Ecole Polytechnique's « Ingénieur » Program*

Evaluation: ***oral exam***

Total number of hours : 36h
Total number of credits (ECTS) : 4

Main professor: Kees van der Beek

Teaching form:
Lectures and labwork

Mention: ***Magnetism and Superconductivity***

Objectives : *The aim of this course is to discover magnetism or superconductivity through experimental works.*

Outline

Magnetism and superconductivity are two fields of research that not only stimulate much interest due to the phenomenology of the materials involved (such as magnetic levitation, phase transitions, zero resistance in superconductors), they are also the two fields of research in which quantum mechanics manifests itself at the macroscopic level.

This module, closely linked to the course « Quantum physics of electrons in solids », proposes the in-depth study of one or the other phenomenon. In the last five years, a subject in magnetism has alternated with a subject in superconductivity, magnetism in even years, superconductivity in odd years.

The operatory mode is to select a topic that is of present scientific interest. The course then presents a theoretical study of this topic, alongside laboratory experiments using state-of-the-art equipment.

Amongst recent subjects:

In Magnetism:

2010: Tunnel magneto-resistance in Permalloy – aluminate – cobalt trilayers

2008 : Spin density wave transition in Chromium nanowires

2004 : Magnetic shape anisotropy in Nickel nanowires

In Superconductivity:

2009: Link between structure and superconductivity in an iron pnictide compound

2009 : Paramagnetic Meissner effect

2007 : High temperature superconductivity

Teachers: *Kees van der Beek , Laboratoire des Solides Irradiés, Ecole Polytechnique, PALAISEAU
Javier Briatico , Unité Mixte de Physique Thalès – CNRS, PALAISEAU*

Prerequisites: *The lecture course « Quantum physics of electrons in solids » proposed by Prof. A Georges*

Course given in common with: *« Quantum physics of electrons in solids » proposed by Prof. A Georges*

Maximum number of students: 8

Evaluation: **30 min oral examination** + 40 p written report.

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- ◆ Total number of hours : 45 h
 - ◆ Total number of credits (ECTS) : 4

Main professor: Nicolas Dubreuil

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: ***Nonlinear optics***

Objectives : *Since laser was invented, a new dimension was opened in optics, ushering in the non linear world with already numerous applications to light sources and optical processing of information. This course will introduce the students to this domain and enable them to fully master its innovative aspects. It describes the physics of the non linear interaction between light and matter from a perturbation approach and shows its consequences on the propagation of optical waves. It describes in detail the second and third order non linear effects rich in applications.*

Outline

Lect	PSS
13.5 h	7.5 h

- ◆ *Introduction to non linear optics*
- ◆ *Non linear propagation of optical waves*
Atomistic bases of Maxwell theory. Linear susceptibility, linear propagation. Non linear response and non linear susceptibility. Non linear propagation equations.
- ◆ *Second order non linear effects*
The Manley-Rowe relations. Second harmonic generation. Frequency mixing, Parametric amplification and oscillation.
- ◆ *The microscopic theory of susceptibility.*
Local field and polarizability. Dynamics of a system of particles in an electromagnetic field. Description of a system of particles by the density matrix. Simplified calculation of polarizabilities. The 1st order polarizability. 3rd order resonant phenomena. The polarizability mechanism. Calculus of electronic polarizabilities. Influence of the local field. Non linear materials
- ◆ *Third order non linear effects*
Introduction. 4 wave mixing and phase conjugation. The dynamic Kerr effect (optical bistability, self focusing, self phase modulation and soliton propagation. Spontaneous and stimulated diffusions (Raman, Brillouin, Rayleigh and Rayleigh wing). Two photon absorption.

Teachers: *Dr N. Dubreuil (IOGS)*

Course given in common with: *M1 Erasmus Mundus OpSciTech*

Evaluation: *3h written exam*

Total number of hours : 21 h
Total number of credits (ECTS) : 3

Main professor: Gaele Lucas-Leclin

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: *Semiconductors physics and components*

The aim of this course is to provide a basic understanding of semiconductor physics, and to describe major optoelectronics semiconductor-based components as photodetectors and semiconductor light sources.

Outline	Lect	PSS	LW
	21.5 h	2.5 h	1 h
◆ <i>Introduction; semiconductor crystal structure and electronic energy bands</i>	4 hrs		
◆ <i>Electrons and holes in semiconductors</i>	3 hrs		
<i>Doping; equilibrium carrier concentrations</i>			
◆ <i>Carrier action in semiconductors:</i>	4 hrs		
<i>Drift and diffusion; p-n junction</i>			
◆ <i>Semiconductors under nonequilibrium conditions</i>	2.5 hrs		
<i>optical joint density of states, continuity equation, quasi-Fermi levels,</i>			
◆ <i>Radiative transitions in semiconductor crystals</i>		1 h	
<i>Absorption, spontaneous and stimulanous emisson; optical gain</i>	2 h		
◆ <i>Semiconductor photodetectors</i>		1 h	
◆ <i>Semiconductor light sources</i>	2 h	0.5 h	
	4 h		

Teachers: *Elizabet Boer-Duchemin (Assistant Professor) – LPPM, Univ Paris-Sud*
Gaëlle Lucas-Leclin (Assistant Professor) – LCFIO, Univ Paris-Sud

Prerequisites: *Optics, Laser physics*

Course given in common with: *Master Erasmus Mundus OpSciTech (1st year) at Institut d'Optique*

Maximum number of students: 20

Evaluation: *2h written exam*

Total number of hours : 24 h

Total number of credits (ECTS) : 3

Main professor: Jean-Michel Jonathan

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: ***Guided and coupled waves***

Objectives : *The course provides the physical bases for some major components of optical communications, such as optical waveguides and fibers, passive or active components. The first section describes (mostly in the weak guidance approximation) the optical modes propagating in guiding optical structures and provides notions such as modal dispersion and losses, central to telecommunications. The second section details the tools for using the electro-optic and acousto-optic effects in their applications for the modulation and the coupling of free space as well as guided optical modes.*

Outline

Lect PSS

18 h 9 h

Guided optical waves

- ◆ *The optical modes in planar waveguides*
- ◆ *Optical fibres in the weak guidance approximation*
- ◆ *Introduction to optical fibres technology*

The linear coupling of optical waves

- ◆ *The linear and quadratic electro-optic effects*
- ◆ *The acousto-optic effect*
- ◆ *The coupled wave theory and its application to the coupling of plane waves*
- ◆ *The coupling between guided modes*

Teachers: *Prof. J. M. Jonathan (IOGS)*

Course given in common with: *IOGS (2nd year)*

Evaluation: *3h written exam*

Total number of hours : 27 h

Total number of credits (ECTS) : 3

Main professor: Bernard Dré villon

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: ***Nanomaterials and applications***

Objectives : *This module introduces recent developments in the field of semiconducting nanomaterials based on carbon or silicon, as well as their main electronic applications.*

Outline

Lect	PSS
18 h	18h

- *Disordered semiconductors: amorphous hydrogenated silicon*
- *Nanocrystalline or polycrystalline silicon*
- *Photovoltaic applications*
- *Flat panel displays*
- *Carbon nanotubes: growth and structure*
- *Electronic applications of carbon nanotubes*
- *Characterization techniques for nanomaterials: near-field and spectroscopy*
- *Molecular electronics*

Teachers: *Prof. B. Dré villon, Prof.. R. Ossikovski (Ecole Polytechnique)*

Prerequis ites: *Solid-state physics, optics, ...*

Course given in common with: *Ecole Polytechnique's « Ingénieur » Program*

Evaluation: ***oral exam***

Total number of hours : 36 h
Total number of credits (ECTS) : 4

Main professor: Emmuel Rosencher

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: *Optoelectronics*

Objectives : *The field of Optoelectronics is currently in full expansion. It emerges from a fascinating interplay between the optical and electronic properties of Matter. The applications of optoelectronics span many fields of activities: telecommunications, energy, data processing, Defense and medical instrumentation, ... Although very sophisticated concepts are at stake in optoelectronics, such as quantum optics, solid state physics, electromagnetism....., the industrial and commercial impact of this discipline is enormous and instantaneous.*

The Course clearly needs a background in Semiconductor Physics. It starts with a detailed study of the semiconductor laser diode, with an emphasis put on the electron-photon balance equations. The implications of these devices in Telecommunications and industrial processing is largely discussed. Then quantum photodetectors are described, with a special emphasis on the breadth of applications covered by this technology such as CCD cameras, solar cells, infrared imagers ...A state of the art of new quantum devices will be given, such as quantum cascade lasers and detectors, quantum well infrared photodetectors,...The impact of nanostructures in optoelectronics is the subject of a special lecture, dealing with Purcell effect, quantum dots, single photon emitters,... Optical parametric oscillators are then described, using both quantum and classical points of view. The recent developpements dealing with artificial materials, optical synthesizers, terahertz emission will be also presented.

Outline

Lect PSS

18h 18 h

The following lectures deal with electromagnetism tools for optoelectronics:

- propagation in dispersive materials (Lorenz model, parabolic equations, bandwidth limitation for Internet,...)

- Waveguides

- Bragg mirrors, metamaterials and photonic crystals

A special emphasis is put on the analogies between quantum wells and waveguides on the one side, Bragg mirrors and energy bands on the other side.

The last lecture is devoted to laser modelockings (active and passive) which are harnessed in a new generation of ultrafast (attosecond) and ultrapowerful (terawatt peak power) lasers.

Teachers: Prof. E. Rosencher (Ecole Polytechnique)

Course given in common with: Ecole Polytechnique's « Ingénieur » Program

Evaluation: **3h written exam**

Total number of hours : 36 h

Total number of credits (ECTS) : 4

Main professor: Silke Biemann, Thierry Gacoin

Teaching form:
lectures (Lect)

Mention: ***Functional thin films and active surfaces : research and innovation***

Objectives : *Many industrial high tech products owe their functionality to the use of thin films, or functionalized surfaces or interfaces. This course aims to give the students a global view of research and development activities in the field, with illustrations ranging from materials used in optical devices, electronics (display and visualisation devices, solar cells ...) to surface treatment (control of wetting, adhesion, catalysis ...).*

Outline

Lect

The course consists of a series of scientific talks given by specialists in the field (researchers or engineers), who are involved in developing new products with original functionalities. 36 h

In addition to the conferences, the students will conduct a personal project, whose aim it is to further elaborate on the scientific, technical and socio-economical aspects of a chosen topic related to the conferences.

Teachers: *Prof. S. Biemann, Prof. T. Gacoin (CNRS)*

Course given in common with: *Ecole Polytechnique's « Ingénieur » Program*

Evaluation: *3h written exam*

Total number of hours : 36 h

Total number of credits (ECTS) : 4

Main professor: Jean-Jacques Greffet

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: *Statistical Physics*

Objectives : *The aim of this course is to provide an introduction to the key concept of statistical physics.*

Outline	Lect	PSS	LW
	<i>n h</i>	<i>m h</i>	<i>l h</i>
◆ <i>Introduction to statistical physics. Classical approximation.</i>	1.5	3	
◆ <i>Microcanonical and canonical ensembles. Work and heat. Irreversibility.</i>	1.5	3	
◆ <i>Grand canonical ensemble.</i>	1.5	3	
◆ <i>Thermodynamics limit.</i>	1.5	1.5	
◆ <i>Quantum statistics (Bose-Einstein and Fermi-Dirac). Classical limit.</i>	1.5	3	
◆ <i>Blackbody radiation.</i>	1.5	1.5	
◆ <i>Real gases.</i>	1.5	1.5	
◆ <i>Thermodynamics</i>	1.5	1.5	

Teachers: *Jean-Jacques Greffet (Pr), Institut d'Optique, François Marquier (Maitre de Conférences), Institut d'Optique.*

Prerequisites: *Introduction to quantum physics*

Course given in common with: *Institut d'Optique and Master Optique M1, de la Science à la Technologie.*

Maximum number of students: 45

Evaluation: *3h written exam*

Total number of hours : 30 h

Total number of credits (ECTS) : 3

Main professor: Catherine Krafft

Teaching form:
lectures (Lect), problem solving sessions (PSS)

Mention: ***Electrodynamics: Continuous media, Structures and Metamaterials***

Objectives : *This course starts from the electrodynamics of continuous materials, and from there, capacitive and inductive structures, antennas, wave guides and lines are studied. By further assembling these structures, meta materials are considered.*

Outline

Lect	PSS
18 h	9 h

- ◆ *Electromagnetic fields:*
the Helmholtz, Green and Stokes theorems . Poynting theorem. Active and reactive power.
- ◆ *Conducting media:*
Free charges, Ohm and Fick law. Charges relaxation. Currents diffusion.
- ◆ *Dielectric media:*
Dielectric dipoles, polarization, susceptibility and permittivity. Interfacial, ionic and electronic polarization.
- ◆ *Magnetic media:*
Magnetic dipoles; magnetization, susceptibility and permeability.
- ◆ *Capacitive and inductive structures:*
Capacitive and inductive structures, capacity and inductance matrices. Reciprocity theorem, Foster and Slater theorems.
- ◆ *Propagative structures:*
Theory of transmission lines and wave guides.
- ◆ *Radiative structures:*
Elements of the antenna theory : gain and impedance. Capacitive and inductive antennas.
- ◆ *Meta-materials:*
Passive synthesis of impedance. Propagation in periodic media. Meta-materials

Teachers: *Prof. T. Minea (University Paris XI)*

Course given in common with: *MI Erasmus Mundus OpSciTech*

Evaluation: *3h written exam*

Total number of hours : 27 h
Total number of credits (ECTS) : 3