	First semester (in REIMS)
EUR01	
	Mathematical and numerical tools for physicists
	Mathematical and numerical tools for physicists :
	Algorithmic and programming
	Models and discretization with finite element method.
	Numerical simulation for partial derivatives equation. Practical work or demo: applications on numerical differential equations systems and numerical tools to solve problems in optics.
	Probability, statistics and inverse problems.
	Statistic physics: Introduction to Fermi-Dirac and Bose-Einstein statistics.
	Main related text books:
	GUM : Evaluation of measurement data — Guide to the expression of uncertainty in measurement, Joint Committee for Guides in Metrology.
	Ramalho, L. Fluent Python: Clear, Concise, and Effective Programming
	Tarantola, A. Inverse Problem Theory and Methods for Model Parameter Estimation. (https://doi.org/10.1137/1.9780898717921)
EUR02	
	Wave optics
	wave optics
	The objective of this course is to give students a solid background in optical wave propagation, with emphasis towards application to
	integrated optics and optoelectonic devices: diffraction, interferometry, polarization, lasers, optical fibers,
	- Wave optics and applications:
	Includes Practical work or demo: Fourier optic (filtering), Michelson (refractive index measurement), Fabry-Perrot, ellipsometry.
	 Gaussian Optics: Propagation and properties of Gaussian beams, ABCD matrix, adaptation and focusing of Gaussian beams, application to integrated
	optoelectronic devices (coupling losses).
	Practical work or demo: laser to optical fiber coupling.
	- Dielectric waveguides:
	Includes more advanced topics such as plasmonics.
	Dielectric waveguides: Propagation in dielectric waveguides (planar waveguides, strip waveguides), application to integrated
	optoelectronics, mode adapters. Introduction to plasmonics. Practical work or demo: propagation in optical fibers, simulation of planar waveguides.
	Main related rext books:
	Saleh, B. E. A & Teich, M. C. Fundamental in Photonics
	Ciarlet, P. G. The finite element method for elliptic problems
	Ern, A. and Guermond, J.L. Theory and Practice of Finite Elements. Applied Mathematical Sciences, Vol. 159, Springer-Verlag, New York.
	http://dx.doi.org/10.1007/978-1-4757-4355-5
	Quarteroni, A. Numerical models for differential problems. Modeling, Simulation & Applications Springer, Cham, Third edition (2020)
EUR03	Solid state Physics
	- Basis of solid state physics:
	Crystal structures (Bravais network. Reciprocal network).
	Experimental probes of real space (near field microscopy) and of reciprocal lattice (Diffraction methods, neutrons, or electrons).
	Electrons in a periodic potential, Bloch's Theorem, band structure, Fermi surfaces and Brillouin zones, nearly free electrons model.
	Application to some metals.
	Practical work or demo: XRD - Lattice vibration:
	Classical theory (normal mode with one- and three-dimensional monoatomic Bravais network), quantum theories of the Harmonic crystals,
	elementary theory of the phonon dispersion relation, electron-phonon interaction. Thermal properties in relation to phonons: specific heat of
	the network, Debye and Einstein models, inharmonic effects. Today's research trends: thermal transport at nanoscale, Phonon-phonon
	scattering, interaction phonon-e-, gap indirect, confinement in nanostructures, Phonon transport in phononic crystals, Ballistic heat
	conduction in semiconductor nanostructures, non-Fourier behavior. Practical work: introduction to molecular dynamics - Optoelectronics:
	 Optoelectronics: Introduction (interest of semiconductors, application to electronic and optoelectronic devices, research industry and market perspectives).
	Band structure, occupation statistics, doping. Transport properties: mobility and velocity, drift and diffusion currents. Junctions: Schottky
	diodes and PN junction, current-voltage characteristics. Field effect transistors. Light/semiconductor interaction, introduction to
	optoelectronic devices: photodetectors, LED and lasers. Today's research trends.
	Practical work or demo: Hall effect, XRD
	Main related text books:
	Ashcroft, N. W. & Mermin, N. D. Solid state physics
	Kittel, C. Introduction to solid state physics
	Sze, S. M. Physics of Semiconductor Devices
	Chen, G. Nanoscale Energy Transport and Conversion: A Parallel Treatment of Electrons, Molecules, Phonons, and Photons.
EUR04	Communication, bibliography, conferences
EUR05	Foreign Language (including FLE: French as a foreign langage)
EUR06	Lab Project 1 (1 day/week in a laboratory within the NANO-PHOT consortium)

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Program: - Understand describe optical properties of solid state materials and systems (dielectric, anisotropic, metallic, semiconductor, gratings, multilayers, waveguides, photonic crystals, metamaterials, laser materials) - Select materials and systems to meet identified needs regarding: absorption, transmission, reflection, filtering, confinement, guiding, dispersion, emission, detection, polarization states - Practical skills: setting a solid-state laser, using a laser diode and a detector for gas sensing, using a CAD software to design multilayer filters and waveguides, playing with polarization states of light. Main related text books: Singleton, J. Band theory and electronic properties of solids Fox, M. Optical aves in layered media Snyder, A. W. & Love, J. Optical waveguide theory EUR10 High resolution microscopies and spectroscopies (to be opened) Nonofobrication and nanometerials (to be opened) 6 NOPH01 Nano-optics and nanophotonics The objective is to acquire basic knowledge and know-how in the field of nano-optics, from concepts to applications: subwavelength imaging, plasmonics and optical (biolsensing, photonic circuitry Notably through simulation and experimental workshops. Program: - Understanding and describing the basics of nano-optics and related applications: subwavelength imaging (nanoscopy). - Far-field and near-field imaging: evanescent waves, dipole emitter, nanoantenna Application: subwavelength imaging (nanoscopy). - Pasign (Simulation) and c			
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LAB02 Lab Project 2 (1 day/week in a laboratory within the NANO-PHOT consortium) 6			

EIP01		3 E
	Innovative companies: entrepreneurship, economic intelligence and intellectual properties	
	Goals: allow students to understand the economic and legal environment of innovative companies. Through the theoretical study of the	
	protection and development of scientific innovations (or in other fields) applied to the business. The student will be able to address the practical aspects through participation and observation of the creation of an innovative business.	
	Program: Management of a business creation project (theoretical course and discussion with creators of innovative businesses).	
	Protecting an innovation: national and international legal system, alternative strategies for the protection of ideas	
	Collect competitive information, market analysis methods and their evolution Establish in the company a culture and tools ensuring efficient and differentiating economic intelligence.	
	Third an an an an	
2	Third semester (in TROYES)	30 E
-	be chosen among:	
MC01	Multi-scale characterization	6 8
	The objective is to provide theoretical and practical training in physico-chemical and mechanical characterization techniques, from	
	macroscopic to nanoscopic scale. Students will be asked to synthesize their own sample. Program:	
	Five themes are addressed in order to acquire experimental skills in the following areas:	
	- Surface analysis and technique (pro lometer, atomic force microscope and indentation)	
	 Analysis of the crystallinity of materials (X-ray diffraction) Optical spectroscopy (Absorption and dynamic scattering of light) 	
	- Mechanical tests (hardness, tensile and shear strength)	
	- Optical and scanning electron microscopy	
	Main related text books:	
Q001		6
	Quantum Option and Name Option	
	Quantum Optics and Nano-Optics	
	The objective is to study the behavior of light at the quantum level. Quantum optics deals with single photons or countable photons and their properties. Applications of quantum optics for nano-optics and quantum technologies will be seen	
	Program: At the end of this course, the student would have acquired:	
	- The basic principles of light quantization	
	- The standard formalism of Quantum Optics with examples taken in single photon phenomena, including applications to quantum	
	technologies - The formalism to describe the notion of entangled photons	
	- The quantum optical formalism for describing classical light, either coherent such as laser light, or incoherent such as thermal radiation.	
	The student will see concrete applications from quantum optics such as:	
	 Quantum metrology: thanks to the notion of standard quantum limit (SQL) and squeezed states of light Quantum communications & quantum cryptography for quantum technologies using quantum teleportation and based on single photons & 	
	entangled photons	
	applications of quantum optics in nano-optics will also be addresses	
	Main related text books:	
	Loudon, R. The Quantum Theory Of Light. Oxford Science Publication	
	Gryngberg, G.; Aspect, A.; Fabre, C; Cohen-Tannoudji, C. Introduction to Quantum Optics: From the Semi-classical Approach to Quantized	
	Light.	1
	Cambridge University Press	
	Cambridge University Press Gerry, C. Introductory Quantum Optics. Cambridge University Press	

	Hot topics in nano-optics and nanophotonics	
	The objective is to get knowledges and skills on the main current topics in nano-optics and nanophotonics, including science, technologies	
	and applications, in collaboration with world-class experts, laboratories and companies. The selected topics can vary each year depending on current topicalities.	
	The expected fall 2021 program is:	
	- Deep learning for nano-optics	
	key words: machine learning, inverse problem, optimization, applications	
	- 2D-nanomaterials	
	key words: optical and transport properties, semiconductor nano-platelets, graphene, transition-metal dichalcogenide	
	- Optical nanosources	
	key words: single photon, nano-emitters, hybrid configuration based on weak/strong coupling, nanolasers, integration of sources	
	- Far-field fluorescence nanoscopy key words: Imaging, Epi-fluorescence confocal and 2-photon microscopy	
	TIRFM, PALM, STORM, (STED) nanoscopy	
	- Nanoscale heat and charge transfer	
	key words: nanoIR, hot electrons, phonons, plasmon-assisted chemistry, ultrafast optics	
	Main related text books and key articles:	
	Mertz, J. Introduction to optical microscopy, Roberts and Company Publishers	1
	Lelek, M. et al. Single-molecule localization microscopy. Nature Review - Methods Primers (2021)1:39	
	Hell, S. Far-field optical nanoscopy. Science (2007) 316:1153	
	Zhang, X. et al. Plasmonic photocatalys. 2013 Rep. Prog. Phys. 76 046401	
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LAB03	Lab Project 3 (2 days/week in a laboratory within the NANO-PHOT consortium)	
	Foreign Language (including FLE: French as a foreign language)	
LAB03 MRPROJ		
	Foreign Language (including FLE: French as a foreign language)	
	Foreign Language (including FLE: French as a foreign language) Management of research projects— based on various real cases and practical examples Training on different issues: Identifying a subject and the type of the project: personal interest, challenge for science, technology, society. Fundamental or applied	
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PhD PROGRAM	
PhD thesis in a laboratory within the NANO-PHOT consortium	3-4 years
Courses at UTT (SPI doctoral school):	
multiscale fabrication and characterization of materials	38h
nano-optics and photonics	38h
Entrepreneurship	25h
Scientific information and communication	25h
Valorization and professional insertion	20h
Scientific ethics and integrity	15h