### Master Program

**First Semester (in REIMS)**

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Textbooks</th>
</tr>
</thead>
</table>
| EUR01| **Mathematical and numerical tools for physicists**                        | 6 ECTS  | - 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](https://doi.org/10.1137/1.9780898717921)) |

| EUR02| **Wave optics**                                                            | 6 ECTS  | - Saleh, B. E. A & Teich, M. C. Fundamental in Photonics  
- Clariet, P. G. The finite element method for elliptic problems  
- http://dx.doi.org/10.1007/978-1-4757-4355-5  

| EUR03| **Solid state Physics**                                                    | 6 ECTS  | - Ashcroft, N. W. & Mermin, N. D. Solid state physics  
- Kittel, C. Introduction to solid state physics  
- Sze, S. M. Physics of Semiconductor Devices  

**Second Semester (in TROYES)**

<table>
<thead>
<tr>
<th>Code</th>
<th>Course Title</th>
<th>Credits</th>
<th>Textbooks</th>
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</thead>
<tbody>
<tr>
<td>EUR04</td>
<td><strong>Communication, bibliography, conferences</strong></td>
<td>3 ECTS</td>
<td>-<strong>EUR05</strong></td>
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<tr>
<td>Course Code</td>
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<tr>
<td>LM01</td>
<td>Classical and quantum light-matter interaction</td>
<td>6 ECTS</td>
<td></td>
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<tr>
<td>OPTM01</td>
<td>Materials and devices in optics and optoelectronics</td>
<td>6 ECTS</td>
<td></td>
</tr>
<tr>
<td>EUR10</td>
<td>High resolution microscopies and spectroscopies (to be opened)</td>
<td>6 ECTS</td>
<td></td>
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<tr>
<td>FAB01</td>
<td>Nanofabrication and nanomaterials (to be opened)</td>
<td>6 ECTS</td>
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<tr>
<td>NOPH01</td>
<td>Nano-optics and nanophotonics</td>
<td>6 ECTS</td>
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<tr>
<td>LAB02</td>
<td>Lab Project 2 (1 day/week in a laboratory within the NANO-PHOT consortium)</td>
<td>6 ECTS</td>
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<td></td>
<td>Foreign Language (including FLE: French as a foreign language)</td>
<td>3 ECTS</td>
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**LM01 Classical and quantum light-matter interaction**

The main objective is to lay the foundations for the interaction between light and matter: the bases of classical light-matter electrodynamic interactions, a semi-quantum model and finally a completely quantum model will be studied.

- Classical light-matter interaction
- Black-body radiation
- Einstein coefficients
- Optical amplification and lasers
- Optical non-linear Optical non-linear processes
- Quantum mechanics essentials I
- Quantum mechanicsessentials II
- Semi-classical approach to light-matter interaction
- Rabi oscillation and the dressed state picture
- Density matrix, Pauli operators and Bloch sphere
- Optical Bloch equations
- Applications of the Optical Bloch equations: saturation, optical pumping, dark resonances and EIT

**Main related text books:**

- Keeling, J. Light-Matter Interactions and Quantum Optics. CreateSpace Independent Publishing Platform

**OPTM01 Materials and devices in optics and optoelectronics**

The objective is to study the various optical properties of solid state materials and structures involved in optics and optoelectronics through technological examples in key fields, including sensing, photovoltaics, security and telecommunications.

- Understand and 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 properties of solids.
- Yeh, P. Optical waves in layered media
- Snyder, A. W. & Love, J. Optical waveguide theory

**EUR10**

**FAB01**

**NOPH01**

**Lab Project 2 (1 day/week in a laboratory within the NANO-PHOT consortium)**

**Foreign Language (including FLE: French as a foreign language)**
### 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 semester (in Troyes)  

<table>
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<tr>
<td><strong>EIP01</strong></td>
<td>Innovative companies: entrepreneurship, economic intelligence and intellectual properties</td>
<td>3 ECTS</td>
</tr>
<tr>
<td><strong>MC01</strong></td>
<td>Multi-scale characterization</td>
<td>6 ECTS</td>
</tr>
<tr>
<td><strong>QO01</strong></td>
<td>Quantum Optics and Nano-Optics</td>
<td>6 ECTS</td>
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2 courses to be chosen among:

### MC01 Multi-scale characterization

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:**

- 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*. Cambridge University Press
- Giery, C. *Introductory Quantum Optics*. Cambridge University Press
- Meystre, P. *Quantum Optics*. Springer

**QO01 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 addressed

**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*. Cambridge University Press
- Giery, C. *Introductory Quantum Optics*. Cambridge University Press
- Meystre, P. *Quantum Optics*. Springer
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: nanosR, 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

Lab Project 3 (2 days/week in a laboratory within the NANO-PHOT consortium) 12 ECTS

Lab Project 3 (2 days/week in a laboratory within the NANO-PHOT consortium) 12 ECTS

Management of research projects— based on various real cases and practical examples 2 ECTS

Training on different issues:
- Identifying a subject and the type of the project: personal interest, challenge for science, technology, society. Fundamental or applied project? With or without industry? State of the art: positioning the subject!
- Definition of workpackages
- Definition of a schedule (Gantt Chart.) with milestones
- Definition of partners: complementarity, skills...
- Definition of the needs and means: people, instruments, consumables...what does one already have? What should be got?
- What is the cost of the project? Can the project earn money? How to finance the project? (sponsoring, calls to be identified)
- The funding organizations
- Writing a good project to efficiently response to official calls for projects
- Implementation of the project: Team to be set-up/hired, projects meetings, project reports: actual achievements, to be compared with the expected milestones, real time assessments, people managements, Communication and outcomes: publications, conferences, patents, prototypes, complying with the expectation of the funders, Intellectual property: patents and others, efficient use of the available platforms/facilities

Fourth semester 30 ECTS

ST30 6-month master internship --> master thesis, master diploma 30 ECTS

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 38%
- nano-optics and photonics 38%
- Entrepreneurship 25%
- Scientific information and communication 25%
- Valorization and professional insertion 20%
- Scientific ethics and integrity 15%