# Master de Physique Fondamentale: Quantum and photonic technologies (QPT)

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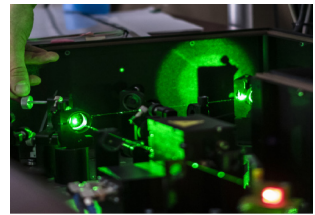
# General overview

The Quantum and Photonic Technologies Master track in Fundamental Physics in a few sentences:

- Train **physicists** capable of addressing major 21st-century scientific challenges.
- Wide range of scientific areas: quantum physics, photonic, condensed matter, statistical physics and more
- The program trains adaptable students with strong analytical and technical skills, and independent learning capacity.

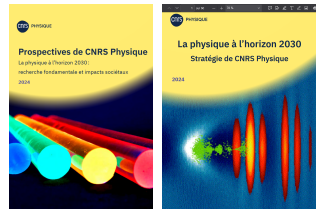


# National and international contexts

A formation integrated in the mid-term national challenges: Prospectives de CNRS Physique-La physique à l'horizon 2030 and Stratégie de CNRS Physique

- Emerging scientific areas (Thématiques scientifiques en émergence)
  - Advanced electronic and photonics
  - Extreme regime of physics
  - Matter, light and quantum processes
- Societal challenges (Grands défies sociétaux)
  - Physics for quantum and numerical technologies

but also at the European level!




EUROPEAN
COMPETENCE FRAMEWORK FOR
QUANTUM TECHNOLOGIES (CFQT)

Reference framework for planning, mapping and comparing QT-related educational activities, personnel qualifications and job requirements.

Version 3.0 (April 2024)
compiled by Franziska Greinert and Marvin Müller, QUEAPS

# Affiliated research labs and programs




- Partly supported by the national initiative QuanTEdu France which promote quantum physics teachings.
- Associated to the Graduate Program " Complexity dans les mondes physiques et numériques", which regroup Master program in mathematics, nanotechnology, electronic, turbulence, etc.

# What skills you will acquire

- **Training scientists** in and through research.
  - Inquiry and critical thinking,
  - Contextualization (state of the art),
  - Modeling and prediction,
  - Experimentation and validation.
- General physics concepts with broad applicability.
- A coherent curriculum, with strong connections and interdependencies across courses.
  $\Longrightarrow$ Coordinated teaching teams
- Student-centered adaptation in support of academic excellence
  $\Longrightarrow$ Innovative pedagogical approaches
- Emphasis on project-based learning and internships.
  $\Longrightarrow$ Autonomy and initiative

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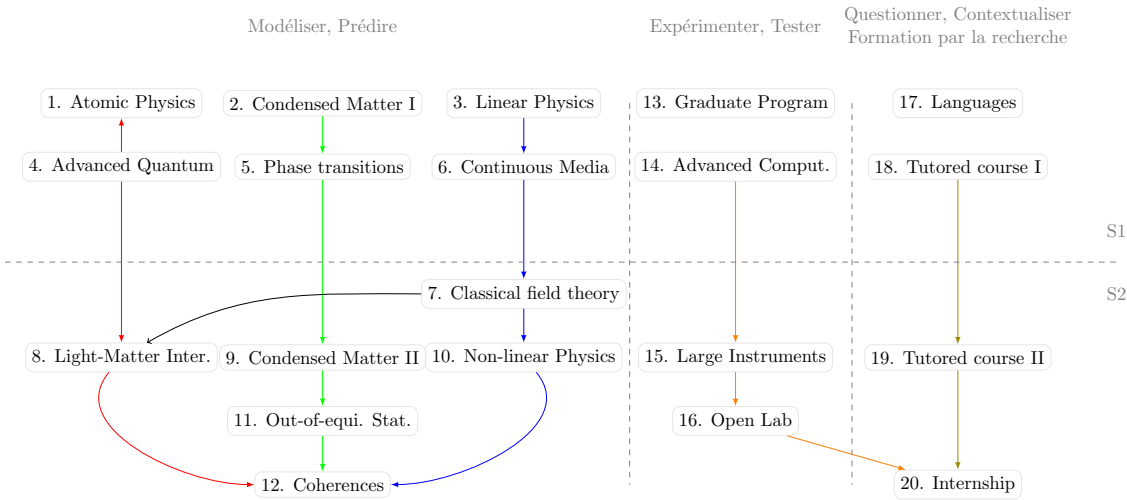
# General structure - Master 1: courses

| **Semester 1** | ECTS |
|---|---|
| Advanced quantum physics | 3 |
| Linear systems | 3 |
| Stat. physics and phase transitions | 3 |
| Atomic physics | 3 |
| Condensed Matter I - Electrons | 3 |
| Continuous media | 3 |
| AI and advanced computations | 3 |
| Graduate Program | 3 |
| Tutored training | 3 |
| English/Francais | 3 |

| **Semester 2** | ECTS |
|---|---|
| Condensed matter II - Phonons | 3 |
| Classical field theory | 3 |
| Light-matter interaction | 3 |
| Out of equilibrium stat. physics | 3 |
| Non-linear dynamics | 3 |
| Classical and quantum coherences | 3 |
| Large instruments | 3 |
| Projects (Open lab) | 3 |
| Tutored training | 3 |
| Internship | 3 |

# General structure - Master 1: relations



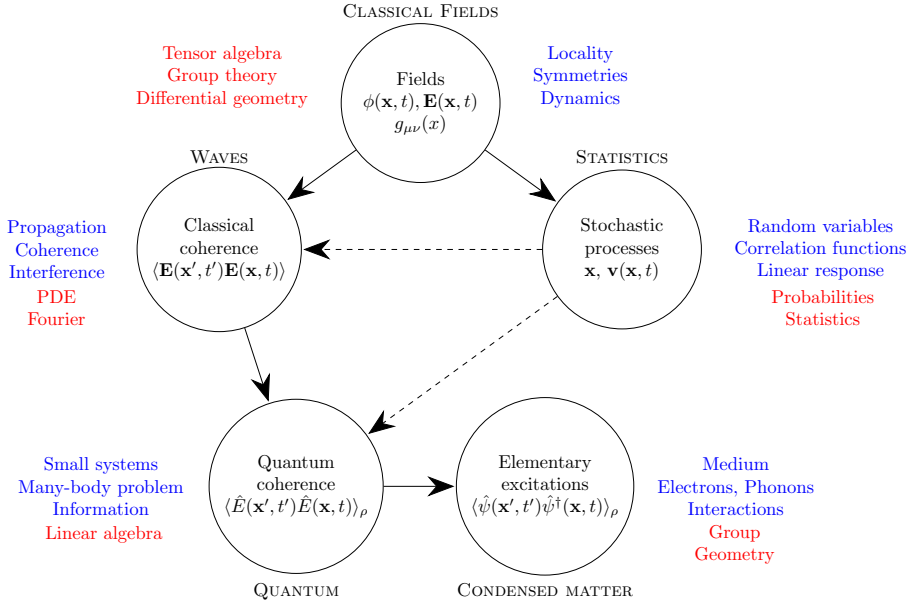
# Detailed structure - Master 1: Semester 1

| **Semester 1** | Contents (indicative) |
|---|---|
| Advanced quantum theory | Path integral, Dirac, time-dependent perturbation, $2^{nd}$ quantization |
| | Two-level systems, density matrix, entanglement |
| Linear systems | Fermat, Propagation of waves, dispersion relations, Fourier |
| Atomic physics | Fine structure, Zeeman, Stark (+Lamb), Hyperfine |
| | 2+more electrons, L-S, j-j |
| Stat.phys. and phase trans. | Ising, Landau, mean field, Bose-Fermi gas |
| | B.E. condensation, renormalization group |
| Condensed Matter I - Electrons | Electrons, Bands, Fermi Surface, metal/insu, Interactions |
| Continuous Media | Tensors, Elasticity, Plasticity |
| AI and advanced computations | Machine Learning et Applications |
| Graduate program | |
| Tutored training | Choose a subject (Nuclear and Particle physics, Biophysics, ...) |

# Detailed structure - Master 1: Semester 2

| **Semester 2** | Contents (indicative) |
|---|---|
| Condensed Matter II - Phonons | Crystalline structure, phonons (quasi-particles) |
| Large Instruments | LIGO-VIRGO, LHC. Synchrotron, telescopes. |
| Classical field theory | Action, Lagrangian, Hamiltonian of a field, Symmetries, Noether, Lagrangian/Relativistic formulation of Maxwell |
| Light-matter interaction | Field quantization, State of light, Semi-classical limit, Laser |
| Out-of-equilibrium stat. phys. | Brownian motion, Langevin, Fokker-Planck, Markov chains Linear response, Correlation functions |
| Non-linear dynamics | Phase space, Bifurcations, Stability, Oscillations |
| Classical and quantum coherences | Classical light (random sources, interf.), quantum light (HBT, HOM), many-body coherence |
| Tutored training | Choose a subject (General Relativity, Hydro-Soliton-Turbulence Quantum Field Theory...) |
| Internship | 3 months in academia or in companies |

# Detailed structure - Master 1: concepts

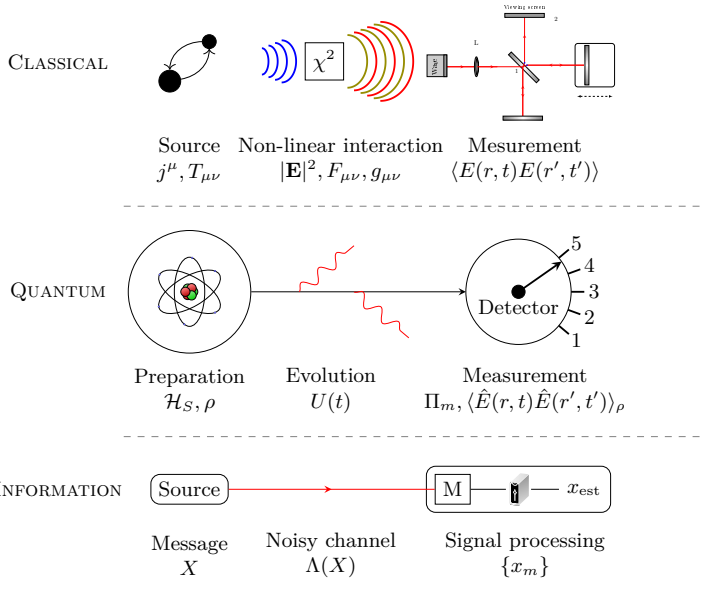


# General structure - Master 2 - Quantum and photonic technologies

**Become a specialist in quantum and/or photonic physics!**

- Prerequisite: equivalence to a M1 level in physics.
- Master track structured on "European Competence Framework for Quantum Technologies"
- Relies on longstanding expertise in photonic and quantum physics in ULille labs.
- Format: Intensive courses plus projects and seminars.
  $\Longrightarrow$ Complete the goal of autonomous learning
  Ready to start a PhD or work in private sector.

# General structure - Master 2: develop a specialist perspective



# General structure - Master 2 - Quantum and photonic technologies

| **Semester 3** | | ECTS |
|---|---|---|
| Photonic technologies | | 6 |
| Quantum and classical information | | 3 |
| Hot topics - Tutored training | | 3 |
| Quantum systems and simulations | Complexity in photonics | 6 |
| Quantum metrology and sensors | Ultrafast measurement microscopy | 3 |
| Quantum computation | Advanced photonics | 3 |
| Graduate program | | 3 |
| English/Français | | 3 |
| **Semester 4** | | |
| Experimental and numerical tools/methods ? | | 3 |
| Internship, up to 6 months in academia or in companies | | 27 |

# Detailed structure - Master 2 - Quantum and photonic technologies

| **Semestre 3** | Contents (Indicative) |
|---|---|
| Quantum and classical info | Concepts: Shannon, von Neuman entropy, mutual information,.. protocols and operational interpretation |
| Photonic technologies | Optical technologies: Non-linear optics, anisotropic optics, $\chi^2$ Sources (lasers, VUV, X, ThZ,...), Fibers |
| Quantum systems | Quantum building blocks i.e. « lego »: Spins, Jaynes-Cummings,... Open quantum systems: Lindblad, decoherence, trajectories,... Quantum « engineering »: cavity/circuit QED, cold atoms, meso, polaritons,... |
| Quantum computation | Algorithms : Gates, universality, circuit, sub-routines, complexity |
| Quantum metrology | Basics: Quantum limit, SI units, criteria Measurement devices: Atomic clocks, EM sensors,... |

# Detailed structure - Master 2 - Quantum and photonic technologies

| **Semester 3** | Contents (Indicative) |
|---|---|
| Complexity in photonics | Non-linear dynamics, topology, telecom NL solitons, frequency combs, cavity solitons |
| Advanced photonics | Propagation in complex media, photonic fiber, metamaterial |
| Ultrafast mea. micro. | microscopy, endoscopy, imaging |
| Exp. and num. tools/meth | NV sensors, Signal processing/Noise (sampling, time-frequency analysis,... Qiskit, Modeling the noise, Detection of GW, Spectroscopy Open lab, Clean room |

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# Job opportunities

For a large panel of job opportunities related to physics studies, visit the SPF (Société Française de Physique) website (in French):

- Academia: PhD in fundamental physics, with specialty in quantum and photonic physics.
  - Research career in Universities, CNRS,...
  - Research support technician
- Industry: work in companies developing quantum technologies and photonic technologies.

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# How to apply

The "Etudes en France" (Studying in France) procedure

- Applies to 70 countries
- Create an account on the "**Study in France**" platform and apply
- Deadlines: **mid-December**, probably
- Will take care of admission procedures and visas

Students with no procedures on "Etudes en France"

- 1st year: use **monmaster.gouv.fr** internet platform, the French national platform for information and applications for a national Master's degree. Applies to
  - International students residing in France;
  - Students who are citizens of or reside in a country in the European Economic Area;
  - International students who reside in a country that is not covered by the "Etudes en France" procedure.
- 2nd year: apply directly to the University, on a plaform called **e-candidat** (same conditions as above)
- Deadline: **spring 2026.**

"Etudes en France" is mandatory if you do not meet the conditions above. Do not try to apply directly. We can not accept applications that do not follow the procedure.

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More information and updates: Visit the website!

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