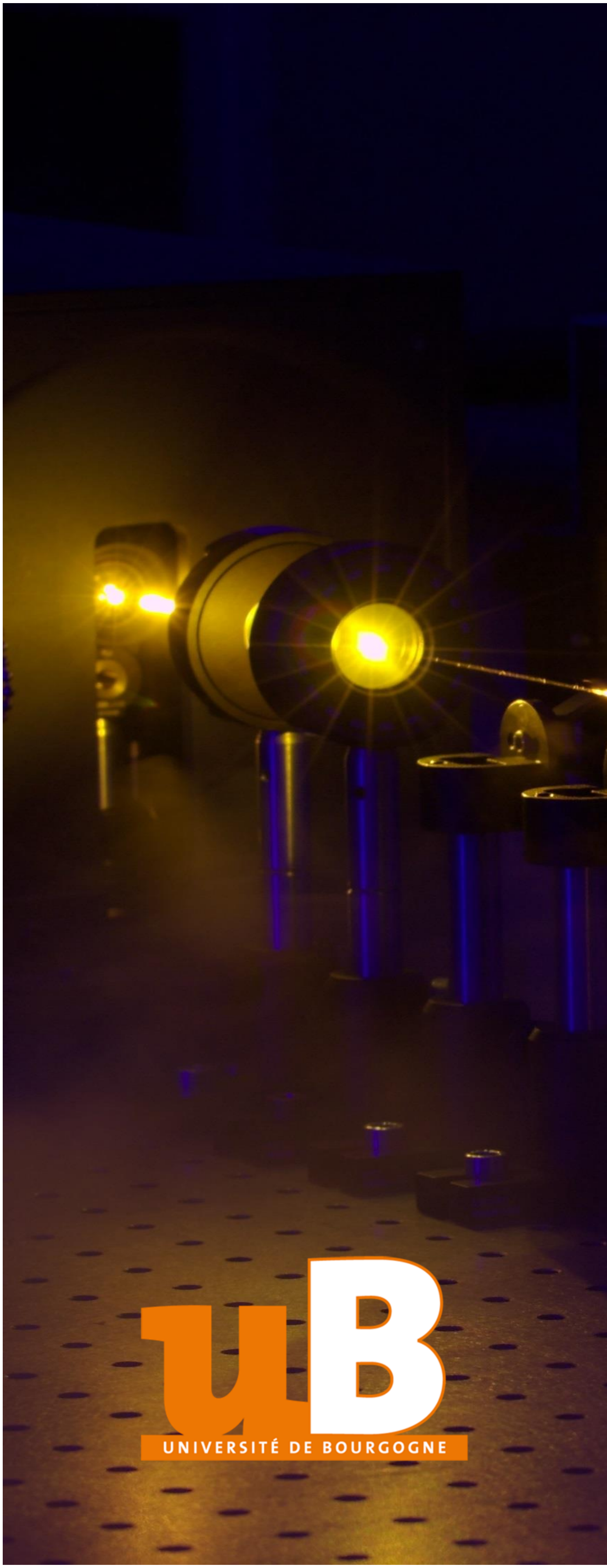

Master

Physics, Photonics & Nanotechnology

MENTION

PHYSIQUE FONDAMENTALE ET APPLICATIONS

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UFR sciences & techniques

2nd Year

UE 1	Quantum Technologies
	S. Guérin, D. Sugny, F. Holweck, C. Latune
5 ECTS 44 H	The aim of this course is to present the fundamental concepts and applications of quantum technologies such as quantum computation and cryptography, quantum optics, quantum measurement and quantum simulation. Aspects common to these applications such as quantum control, quantum thermodynamics, quantum entanglement and the basic concepts of quantum information are described. Particular attention is paid to the theoretical notions required for the practical work on quantum technologies carried out in the E.U. Practicals 2.

UE 2	Ultrafast Optics
	O. Faucher, E. Hertz
5 ECTS 40 H	The aim of this course is to present the fundamental concepts and applications of femtosecond laser pulses. In the first part, the linear and non-linear optical phenomena encountered during the propagation of an intense ultra-short laser pulse are described. Mode-locking and pulse compression techniques are then discussed. The second part deals with the modelling of radiation-matter interaction processes in ultrafast optics; pump-probe measurements, terahertz radiation production, quantum beats, harmonic generation, Raman effect, photon echo. The issues associated with the metrology of ultra-short pulses, and in particular their temporal characterisation, are dealt with in the third part. The last part deals with the various techniques for establishing temporal shaping of femtosecond laser pulses, ranging from simple methods with few control parameters (stretcher, compressor) to the most elaborate shapers allowing extensive control of pulse shape. /Knowledge: Understand the techniques for producing, characterizing, and tailoring an ultra-short laser pulse. Know how to model the physical processes resulting from the interaction of a laser pulse with a quantum system using the Bloch Optics equations. Understand the principle of most common temporal characterization techniques (autocorrelation, FROG, SPIDER, etc.) and

	pulse shaper devices (stretcher, compressor, shaper using SLM and 4f line, dazzler, etc.).

UE 3	Advanced Fiber Photonics
	P. Grelu, F. Smektala, B. Kibler
5 ECTS 52 H	This course presents: a) the fundamental physical effects and concepts underlying the propagation of short and ultra-short optical pulses in dielectric waveguides - b) fibre optic amplifiers and fibre lasers. Dynamics of ultrafast fibre lasers. Dissipative optical solitons -c) Supercontinuum generation; nonlinear waves and rogue events; multimode fibres, transmission of orbital angular momentum, numerical modelling. - d) Glasses and their optical properties Oxide, fluoride and chalcogenide glasses, non-linear optical properties, hybrid fibres, new 3D manufacturing technologies.

UE 4	Nanophysics, Nanophotonics
	G. Colas des Francs, A. Dereux, B. Cluzel
5 ECTS 60 H	This module deals with the optical and physical properties of micro- and nanostructured solid materials. Guided and localised modes in dielectric layered media, both periodic and non-periodic, are presented in the first part. Miniaturised optical resonators are then discussed and we introduce the notions of strong coupling, weak coupling and the Purcell effect when coupled to single emitters such as semiconductor quantum dots or quantum wells. In the second part we consider metals and the special case of surface plasmons/polaritons. We review the properties of both propagative and localized surface plasmons to manipulate and concentrate the flow of light at nanoscale. Through numerical tutorials using the resources of the university's computing centre, followed by independent personal projects, the students are encouraged to apply the numerical methods studied in order to determine the usual optical and physical properties of micro-nanostructured materials, such as : - the dispersion relations for electromagnetic modes within volumes, surfaces, thin films and multilayers; - the reflectivity, transmission and absorption of systems with planar symmetry; - the light scattering by small metallic and dielectric particles (Mie resonance, Fröhlich resonance, etc.); Through the personal projects carried out, this teaching module reproduces the work expected of a researcher in a laboratory such as: understanding contemporary articles and reference texts, applying the concepts introduced in the articles and texts in projects requiring digital implementation, writing professional quality reports in scientific English.

UE 5	Advanced Microscopies A. Bouhelier, E. Lesniewska
2 ECTS 30 H Contrôle Terminal	Advanced microscopy methods (optical, electron and local probe) applied to nanoscience and materials science. At the end of the course the student will have knowledge of the operating principle of the different types of microscope and their respective fields of application. The physical, physico-chemical and tribological quantities measurable by the microscopy techniques presented will be introduced and the image formation and acquisition process will be detailed in this course. Knowledge: Select and implement advanced microscopy techniques to address a given problem. Interpret image formation and identify sources of artefacts in relation to measurement techniques.

UE 6	Nanobiosciences P. Senet, A. Nicolai - Transverse Lecture
3 ECTS 40 H Contrôle Continu Intégral	Theory and numerical techniques for modelling nano(bio)systems and biomolecules. Mastery of the use of a computer centre, all-atom and coarse-grained molecular dynamics techniques, machine learning and dimensionality reduction techniques for the interpretation of large simulation data sets, theoretical concepts of molecular biophysics and free energy landscapes. Carrying out an advanced project on numerical simulations of nanosystems.

UE 7	Atomic & Molecular Dynamics
	C. Leroy, G. Guillon - Transverse Lecture:
2 ECTS 22 H Contrôle Terminal	This course is in two parts. The first deals with quantum theory, models and methods for collisional processes between atoms and molecules. A connection between the time-dependent and time-independent viewpoints is established. Dynamic observables such as cross section and transition probabilities are introduced. Finally, we propose illustrations with simulations of realistic systems, at high or low energy. At the end of this section, students will be able to model collisional dynamic processes in different contexts and simulate them using numerical tools. The second part deals with the Dirac equation. After a brief review of the basic mathematical tools (Lagrangian, momentum, Hamiltonian, Euler-Lagrange equations), we introduce the first attempt to reconcile quantum physics and special relativity with the Klein-Gordon equation. We demonstrate the limitations of this equation, in particular the problem it poses with the introduction of conservation of probability density, which leads to negative densities. The Pauli equation is then introduced and its limitations explained. We then introduce the argued list of conditions that must be met by a quanto-relativistic equation, which naturally leads to the proof of the Dirac equation. In particular, we explain that the Dirac equation naturally contains the electron spin without the need for additional conditions. Finally, we develop the Dirac equation completely, transforming it to order v^2/c^2 so that all the terms used in atomic physics to study atoms in electric and magnetic fields appear.

UE 8	Tutored Project / Research Project Supervisor in the lab/company
3 ECTS 60 H	Tutored projects and research projects are designed to build skills based on real work situations. In a company, the tutored project involves welcoming the learner into the organisation, providing support and passing on skills, and assessing the learner. At university, the research project is defined around the exploitation of situations, helping to identify the skills the link with knowledge. Lasting 60 hours, it aims to enhance the student's skills in one of the following themes, for example (not exhaustive): - optoelectronic signal analysis - laser design, alignment and characterisation - nanofabrication in clean rooms - instrument interfacing and automation - quantum computing ....

UE 9	Professionnal Setting (work study students) Tuteur industriel
6 ECTS 70 H	The pofessionnal setting is defined with the participation of the host company. Its purpose is to reinforce the student's skills in a specialist technical field at the interface between the training and the technical skills to be developed in the company. An examination will be carried out and assessed within the company jointly by a representative of the training centre and the apprenticeship supervisor.

UE 10	Practicals Session 1 : Fiber Optics C. Strutinsky, A. Coillet
2 ECTS 35 H	The aim of this course is to put into practice the fundamental concepts and tools acquired in the field of fibre optics. The practical work proposed targets key experiments in fibre optics, from the production of fibre optic components to their characterisation and implementation in a hardware network.

	/ Knowledge: To be able to apply the fundamental knowledge acquired in fibre optics in order to produce and test a fibre optic-based hardware network, to measure it and to analyse the results in relation to the concepts.

UE 11	Practicals Session 2 : Quantum Technologies
	O. Faucher, D. Sugny
2 ECTS 35 H	The aim of this course is to put into practice the fundamental concepts and tools acquired in the field of quantum technologies. The practical work proposed targets key experiments in quantum optics on photon entanglement, violation of Bell's inequalities, quantum cryptography and quantum erasers. / Knowledge:To be able to apply the fundamental knowledge of quantum mechanics and wave optics in order to model and predict the results of a quantum technology experiment, carry out measurements and analyse the results. Understand the operation and use of a single-photon source. Know how to adjust an optical device.

UE 12	Practicals Session 3 : Nanophotonics
	B. Cluzel, A. Coillet, F. Chaussard
2 ECTS 35 H	The aim of this course is to put into practice the fundamental concepts and tools acquired in the field of nanophotonics. The practical work proposed targets key experiments at the nanometric scale, such as optical tweezers, surface plasmon resonances, evanescent field coupling and gallery mode resonators, local probe microscopy and confocal microscopy. / Knowledge: To be able to apply the fundamental knowledge of nanophotonics in order to model and predict the results of an experiment involving optical near-field interactions at the scale of a single object, carry out measurements and analyse the results.

UE 13	Practicals Session 4 : Ultrafast Optics/Lasers
	E. Hertz, P. Grelu, A. Coillet
2 ECTS 35 H	The aim of this course is to put into practice the fundamental concepts and tools acquired in the field of ultrafast lasers. The practical work proposed will consist of building a femtosecond fibre laser, characterising a train of pulses, using laser pulses for applications, and handling a laser beam safely in an advanced set-up. / Knowledge : To be able to apply the fundamental knowledge acquired in femtosecond sciences in order to model and predict the results of an experiment involving ultrafast lasers, to carry out measurements and to analyse the results.

UE 14	English/French
	D. Bao
1 ECTS 20 H	The aim of this course is to enable French-speaking students to put their knowledge of the English language into practice in writing and speaking, and non-French-speaking students to acquire a basic understanding of the French language and culture.

UE 15	Internship/Alternance
	Supervisor in the lab/company
20 ECTS 5-6 Mois	Students will use the knowledge they have acquired in a professional context to carry out a project that responds to a specific industrial or research problem. In addition to the technical know-how acquired during the placement or work-study period, which will be specific to the project entrusted to the student, the latter will develop his/her personal organisation skills, teamwork and written and oral communication skills as part of the assessment of this teaching unit. A professional quality report and an oral presentation of the work carried out will be assessed by a panel of academic and industrial experts.