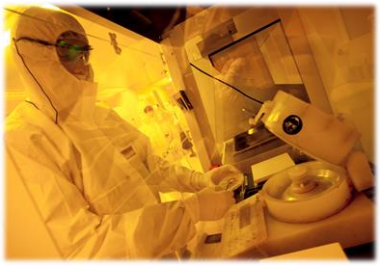
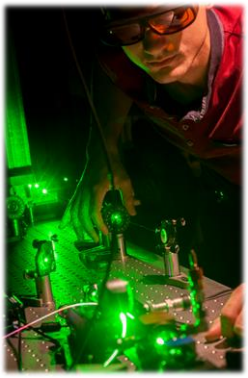
MSc iXeo
(Electronics, Optics and Telecommunications)
Master's Degree

Cutting edge companies and research laboratories need more and more specialists able to design and develop components, devices and complex systems for airborne communications, defence, terrestrial telecommunication networks, to name a few. Our master's degree in Electronics, Optics and Telecommunications is committed to prepare the engineers or researchers of tomorrow better able to respond this challenge.
Most instructors are researchers at XLIM laboratory, a mixed unit between the University of Limoges and the French National Center for Scientific Research (CNRS). iXeo focuses on scientific areas where the laboratory has tremendous experience: guided wave circuits, antennas, active microwave devices and systems, fiber optics, lasers, nonlinear optics. Emphasis is put on practical labs and computer-aided design. The student is embedded in the laboratory for an average duration of 6 months over the two years.

According to the European Credit Transfer System (ECTS), a two-year master's program is worth 120 ECTS (60 ECTS per year).

	ID	Title	Term	ECTS	Hours
Year 1	S7TQ418U	Electromagnetic field theory, application to HF circuits and antennas	S1	9	90
	S7TQ428U	Optical propagation	S1	7	70
	S7TQ438U	Active and non-linear circuits	S1	9	90
	S7TQ448U	Optical and electronic signal processing	S1	5	50
	S8TQ418U	English language	S2	3	30
	S8TQ428U	Lasers	S2	3	30
	S8TQ438U	Nonlinear optics	S2	4	40
	S8TQ448U	Physics and technology for electronic devices	S2	6	60
	S8TQ458U	Passive microwave components, antennas and transmission systems	S2	5	50
	S8TQ468U	Modelling and computer-aided design of microwave devices	S2	6	60

	S8TQ478U	Tutored project	S2	3	30
	S8TQ478U	Specific Pratcial Works at Center for Micro-Nano Electronics in Toulouse	S2	0	30
Year 2	S9TQ518U	Antennas and EM compatibility for RF systems	S1	6	30
	S9TQ528U	Passive components and devices for RF systems	S1	6	30
	S9TQ538U	Nonlinear components and devices for RF systems	S1	6	30
	S9TQ548U	Printed electronics for telecom and energy harvesting	S1	3	15
	S9TQ558U	Telecom systems and networks	S1	1.5	10
	S9TQ568U	Advanced photonic sources and systems	S1	7.5	37.5
	SATQ518U	Computer-aided design	S2	3	90
	SATQ528U	English	S2	6	30
	SATQ538U	Research speciality (bibliographic studies)	S2	6	60
	SATQ548U	Professionnal speciality (Trainings and Pratical Works)	S2	6	140
	SATQ558U	Internship	S2	15	560 to 840

Year 1

Teaching unit S7TQ418U: Electromagnetic field theory, application to high frequency circuits and antennas (90h, 9 ECTS)

Propagation: Maxwell equations, wave equation, dispersion relation, TE and TM waves in metallic rectangular waveguide, TEM wave, telegrapher's equations, coaxial waveguides
Transmission lines: S parameters, Smith chart, passive components (L, C, R, LC) distributed and lumped elements, design methods for circuits, coupled lines theory
Antennas: Basics of electromagnetic field theory, solutions for Maxwell equations, idealized electric dipole, characteristics of antennas (radiation patterns, gain, directivity, wire antennas…)
Labs (24h): ADS Momentum HFSS software, low-pass filter at microwave frequencies, modeling of antennas

Teaching unit S7TQ428U: Optical propagation (70h, 7 ECTS)

Guided wave propagation: Plane waveguides (propagation modes, power coupling, propagation constant, Dispersion relation, transverse mode distribution, dispersion phenomenon), optical fibres (Linearly polarized modes, Gaussian approximation for the fundamental mode, Propagation in presence of dispersion), power

transfer (loss at joints, Overlap integrals, coupled mode theory, Parallel waveguides, Bragg grating, Tapers, adiabaticity criterion)

Free space propagation: spatial frequency, signal processing – time vs space (spatial Fourier transform, spectrum, plane wave expansion, convolution, transfer function), transfer function (plane wave, transfer function), application to the Gaussian beam (spectrum, finite distance propagation, analytic field for a Gaussian beam, examples), Fourier optics (analogy between space and time signal processing, linear system with translation invariance, finite distance diffraction, application of Fourier optics)

Labs (24h): Fusion-splicing machine and power budget, EDFA, numerical transmission, YAG laser, sub-ps laser, strioscopy – filtering of spatial frequencies

Teaching unit S7TQ438U: Active and non-linear circuits (90h, 9 ECTS)

MMIC technology for active circuits: Si, GaAs, GaN, InP technologies for RF front-end in mobile, radar, satellite applications

Characterization and modeling of nonlinear components: nonlinear model for Schottky diode and HEMT transistor, electrothermic model

Study of some non linear functions: High efficiency classes (A-AB-B-C-D-E), nonlinear distortions (compression, saturation, intermodulation, C/I3, IIP3, OIP3, C/I5)

Narrow band and wide band power amplifiers architectures: parallel, cascode, push-pull, multi-stage (adaptation), DC-40GHz amplifier for high bit rate optical receivers

Architectures of non linear circuits with cold HEMT, HF mixers, oscillators

Labs (24h): FET amplifier, network vector analysis, linear and nonlinear modelling of FET with ADS, design of FET power amplifier at 2 GHz with ADS, design of power amplifier (layout, etching, simulation), characterization of power amplifier (vector and scalar network analysis, spectrum).

Teaching unit S7TQ448U: Optical and electronic signal processing (50h, 5 ECTS)

Filtering function in communication systems. Technologies for realizing filters at various frequencies: Analog filter (transfer function, stability of linear circuits, filter synthesis, approximation functions (Butterworth, Tchebychev), filter order. Digital filter (digital transmission line, analysis, filters with finite or infinite impulse response, examples)

Characteristics of modulated signals and application to telecom and radar: Analog and digital modulation formats (AM, FM, phase modulation…), temporal and spectral behaviour, power (average, peak), vector representation, Complex signal and complex envelope, I/Q representation, generation and detection, linear distortion; Transmission systems for satellite communication, radar systems

Labs (12h): Study of filtering functions, switched capacitor filter, introduction to digital filters

Teaching unit S8TQ418U: English (30h, 3 ECTS)

Language objectives: developing the 4 language skills as defined by the CEFRL (Common European Framework of Reference for Languages), listening and reading comprehension, speaking and writing, target level B2 (independent user/ upper intermediate level), discovering language proficiency tests (how the system works: presenting major standardized tests, TOEIC and CLES 2 training)

Content objectives: living and working abroad, discovering companies and research laboratories working in the field: powerpoint presentation, applying for an internship, a job or a position, CV/resume, cover letter, job interview, first steps), introducing research papers (Better grasping original scientific articles by developing, language tools, vocabulary, grammar, methodological tools, structure, outlines), developing science communication skills (working on the MSc project, writing and presenting, group work)

Teaching unit S8TQ428U: Lasers (30h, 3 ECTS)

Rare earth doped fibre amplifiers: Principles (mechanisms for light-matter interaction, rate equations, power equations for 3 level model, spectral behaviour, impact of the fibre geometry, fabrication of rare earth doped fibres), Erbium-doped fiber amplifier for telecoms (system parameters: gain, noise figure,

limitations (e.g. excited state absorption), towards power amplification, Other rare earths (ytterbium, thulium, holmium, neodymium, high-power lasers at 1 and 2 µm, applications: welding, micromachining)
Lasers: Principles (Laser gain for 3 and 4 energy level systems, small signal gain (2-level model), gain saturation, laser oscillator: principle, loss, operating point, characteristics of laser emission: power conversion efficiency, longitudinal modes, transverse modes, laser resonators for single transverse mode operation: Gaussian beam, stability condition, regimes: continuous wave, Q-switched, mode-locked), Examples of all-solid lasers (bulk crystal lasers and fibre lasers) and their applications

Teaching unit S8TQ438U: Nonlinear optics (40h, 4 ECTS)

Introduction to nonlinear optics: Fundamentals of light-matter interaction (polarizability, susceptibility), Second order nonlinear optics (electro-optical effect, Pockels effect, phase and intensity modulation, frequency doubling, phase-matching condition), third-order nonlinear optics (Kerr effect, self-phase modulation, self-focusing, soliton)
Study of nonlinear optical processes: Wave equation in nonlinear regime (nonlinear propagation equation, Maxwell's equations with nonlinear susceptibilities, slowly varying envelope approximation, simplified equations for wave mixing), frequency doubling (low conversion regime, frequency doubling and optical rectification, second harmonic power evolution without phase matching, coherence length, quasi phase-matching condition, high conversion regime), three-wave mixing (wave-particle duality, coupled equations, Manley-Rowe equations, sum frequency generation, difference frequency generation, parametric amplification), frequency tripling, self-phase and cross-phase modulation, Four-wave mixing (phase-matching condition, coupled equations with phase matching), nonlinear scatterings (spontaneous and stimulated scatterings, Brillouin scattering and Raman scattering, complex nonlinear susceptibility, simplified power equations)

Teaching unit S8TQ448U: Physics and technology for electronic devices (60h, 6 ECTS)

Elements of solid-state physics: direct and reciprocal lattices, energy band structure, intrinsic and extrinsic semi-conductors
Study of dielectrics: permittivity and absorption
Charge transport in heterojunctions: example of Schottky diode
PN function: thermodynamic equilibrium, out of equilibrium (direct and inverse currents)
Metal-oxide semiconductor: equilibrium (band bending), out of equilibrium, I-V characteristics
Technologies for fabrication of integrated circuits on Si (epitaxy, doping, oxidation, plasma vapor deposition and chemical vapor deposition processes, lithophotography, etching, realisation of passive integrated elements (R, L, C) and active integrated components (junction, BJT, NMOS, PMOS, HBT SiGe), Cadence software
Passive RF elements for microelectronics (resistors, integrated capacitors and spiral inductors, equivalent circuits, Q factor, transmission lines on conductor substrates)
Labs (12h) MOS technology with TCAD Silvaco, photoreceiver with TCAD Silvaco, fabrication and characterization of spiral inductors.

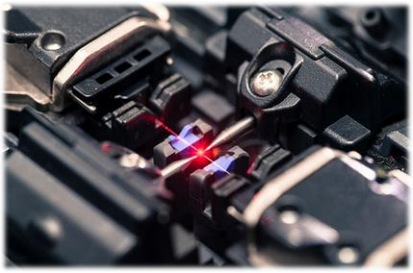
Teaching unit S8TQ458U: Passive microwave components, antennas and transmission systems (50h, 5 ECTS)

Passive microwave components (power in rectangular waveguides, loss, S paraemters, resonators, metallic cavity, resonance frequencies, Q-factor, RLC model, in and out coupling**)**
Antennas: links between antennas (Lorents reciprocity theorem, effective area, gain, Friis formula), networks (linear network, directivity, radiating aperture antennas (Huygues principle)
Labs (24h) Implementatipn of a scalar network analysis bench, characterization of plane waves – Antennas, Characterization techniques for waveguides, Characterization of resonant cavity with network analyzer, Characterization of a multipole resonator, Characterization of printed antennas

Teaching unit S8TQ468U: Modelling and computer-aided design of microwave devices (60h, 6 ECTS)

MMIC technology for active circuits: Si, GaAs, GaN, InP technologies, electrical models for passive MMIC for CAD, example of an MMIC run, wafer cartography
Linear specification for HF quadripoles in CAD: input and output impedances, S parameters, power gain in linear quadripoles, stability of linear quadripoles, adaptation, synthesis
Introduction to non linear CAD
Characterization and modeling of non linear active components: principles, toolbox, example of Schottky diode and HEMT transistor, HBT transistor, varactors
Principle and method for electrothermic modeling
Applications and examples of non linear MMIC circuits (reverse engineering): ultra wide band DC-40GHz receiver, distributed power amplifier
Labs (24h): CMOS technological process, MOS transistor with N or P canal, design methodology for basic logical gates (INV, NAND, NOR), Cadence software

Teaching unit S8TQ478U: Tutored project (30h, 3 ECTS)


Year 2

Teaching unit S9TQ518U: Antennas and EM compatibility for RF systems (30h, 6 ECTS)

EM compatibility: from system complexity to topological mapping for EM compatibility study, perturbation and coupling, system modeling to evaluate coupling, main characterization setups
Antennas: directional antennas for space applications, radiating aperture for satellite communications, agile antennas for wireless communications, analog and digital beamforming, plane arrays and associated circuits, integrated antennas for mobile terminals, multifunction radiating systems, how to miniaturize antennas, MIMO, radar antennas, ultra-wideband antennas and aperture synthesis, wave forms and numerical processing for radar applications.

Teaching unit S9TQ528U: Passive components and devices for RF systems (30h, 6 ECTS)

Propagation: Industrial and R&D context for passive microwave circuits, cylindrical metallic waveguide, EM analysis and modelling of heterogeneous microwave resonators, theory of coupling between microwave resonators, microwave filter synthesis, EM CAD for microwave sub-systems (components, packaging), current research activities

Micro-Electro-Mechanical Systems (MEMS) and associated microwave circuits: Industrial and R&D context for electronic switches and tunable components, parameters and characteristics for HF switches, topologies for SPNT matrices, topologies for switched capacitors for tunable components, semi-conductor technologies and PCM, RF MEMS switches, electrostatic actuator, switch with metal contact, switch with capacitive contact, application example.

Teaching unit S9TQ538U: Non linear components and devices for RF systems (30h, 6 ECTS)

Nonlinear circuits: nonlinear modeling methods for GaN HEMTs, efficiency versus linearity, statistics of complex modulated signals with variable envelope, linearity criterion for modulated signals, strategies for improvement

Low noise amplifier design: noise analysis for linear RF circuits (sources of noise in electronic circuits, noise power vs signal power, noise figure and equivalent noise temperature, noise figure for passive quadripole, Friss formula, noise parameters for linear quadripole, modelling noise in linear quadripole, characterization techniques, noise figure measurement), design and synthesis of low noise amplifier (specifications and modelling process)

Digital processing systems: digital modulation formats, signal processing (IQ formalism, complex envelope, IQ modulation and demodulation, example of M-QAM modulation format, mathematical description of sampling, Nyquist-Shannon theorem), particular case of wireless systems (multiplexing techniques (FD/TDMA), TDD and FDD duplexing with Downlink and Uplink, constraints on RF receivers), receivers architectures, pros and cons (heterodyne vs homodyne, digital IF receiver, receiver with bandpass sampling, receiver with discrete sampling, limitation of analog-digital conversion)

Particular case of Track Hold Amplifier (THA) RF sampler: architecture, example of THA 1321 Inphi datasheet and its use for band-pass sampling with under-sampling for extraction of complex envelope

Teaching unit S9TQ548U: Printed electronics for telecom and energy harvesting (15h, 3 ECTS)

Printed electronics: main applications, physical (electronic and optical) characteristics and parameters of organic materials, deposition processes, application to organic photovoltaics, application to photo-detection, physical (electronic and optical) characteristics of nanostructured materials (quantum wells), focus on hybrid perovskites, application to light emitting diodes, application to lasers, application to visible light communications

Teaching unit S9TQ558U: Telecom systems and networks (10h, 2 ECTS)

Characterization of propagation channels for high bit rate wireless digital communications, single-carrier systems (AWGN), filters at emitter and receiver sides, Nyquist criterion, equalization for single-carrier systems, shortcomings for 4G systems, introduction of multi-carriers modulations, description of Orthogonal Frequency Division Multiplexing (OFDM), synchronization, some examples (UMTS, LTE, WIFI-WIMAX)

Teaching Unit S9TQ568U: Advanced photonic sources and systems (37.5h, 7.5 ECTS)

Basics: Detection (field modelling, space-time behaviour, how to measure phase? field and intensity correlation, relation between spatial and temporal behaviours), propagation (dispersion – diffraction, similarities for a 2nd order description, Gaussian beams and Gaussian pulses, space-time analogy; temporal solitons and spatial solitons), focus on light sources (relevant parameters for light source description, spatial and temporal modes, examples)

Advanced sources:

How to manage the relevant parameters of a coherent source? Parameters for full space-time characterization of the laser radiation, M^2 parameter, autocorrelation trace, Fourier-limited pulses,

diffraction-limited beams, tailoring a coherent radiation (spatial and frequency filtering, space-time analogy, space-time profiling), active and passive control over space-time characteristics

Spatial behaviour: guided wave optics – optical fibre (geometrical vs wave approach, techniques for controlling modal properties), index-guiding microstructured fibres (architecture, analogy with conventional fibres, modified total internal reflection, fabrication, properties), applications to high power sources.

Temporal behaviour: third-order nonlinearities and their impact on the pulse, management of third order nonlinearities for guided waves: microstructured fibres (index and bandgap guiding) vs conventional fibres, control over the propagation constant), single-frequency laser (gas laser, DBR, a few applications to LIDAR, LIGO-VIRGO), partially coherent radiation (evaluation of the mutual degree of coherence, incoherent supercontinuum and application to infrared spectromicroscopy), mode-locked lasers (principles, operation regimes (soliton, dispersion-managed, all-normal, chirped pulse), Raman solitons → application to multiphoton microscopy), frequency combs: coherent supercontinuum for metrology

Teaching unit SATQ518U: Computer-aided design (90h, 3 ECTS)

Optical CAD: FiberDesk (scalar nonlinear Schrödinger equation) for ultrashort pulse generation and propagation, Comsol Multiphysics (full-vector finite element method) for advanced modal analysis of complex structures (microstructured fibers)

RF CAD: ADS for passive and nonlinear RF systems, CST for antennas, HFSS (full-vector finite element method) for RF devices (resonators, filters), Cadence (Virtuoso layout suite) for the design and modelling of semi-conductor components and systems

Teaching unit SATQ528U: English (30h, 6 ECTS)

Language objectives: developing the 4 language skills as defined by the CEFRL (Common European Framework of Reference for Languages), listening and reading comprehension, speaking and writing, target level B2 (independent user/ upper intermediate level), CLES 2 Language Certificate (General English), training (September - November), working on a file related to society issues, skills tests (listening and reading comprehension, written expression and oral interaction)

Content objectives: living and working abroad, applying for an internship, a job or a position, CV/resume, cover letter, job interview), developing science communication skills (oral presentation: thesis topic for PhDs-to-be or a lab experiment), research article writing (checking language skills, lexicon, linguistics, style).

Teaching unit SATQ558U: 3 to 6 months internship (15 ECTS)

Contact info

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