OUTLINE :

First Semester M2 ROSP

- Refresher: 2 elective courses to be chosen

Blocks	Ects	Cours	TD	TP
Refresher: Physics of Optoelectronic Devices	2	10h	3h	6h
Refresher: Communication Networks	2	15h	3h	-
Refresher: Digital Communications	2	20h	-	-

- Core courses

Blocks	Ects	Cours	TD	TP
Optoelectronic Devices	4	29h	5h	4h
Digital Information Processing	3	24h	3h	3h
Error-Correcting Codes and Coded Modulations Applied to Optical Communications	2	15.5h	1.5h	3h
Optical Information Propagation and Point-to-Point Transmission Systems	3	18h	-	12h
Advanced and Next-Generation Optical Transmission Systems	2	12h	-	9h
Optical Networks	4	9h	9h	12h
Future Trends in Optical Networks	2	9h	6h	3h
Photonic Systems Towards Other Applications	3	-	-	18h

- 1 elective course to be chosen

Blocks	Ects	Cours	TD	TP
Fonction et intégration photonique	3	30h	-	-
Nanophotonics	3	24h	-	3h

Second Semester ROSP

Matières	Ects	Cours	TD	TP
Internship	30	-	-	-

DETAILED VERSIONS of each block contents

Refresher: Physics of Optoelectronic Devices

ECTS

2

Mots clés

Description du contenu de l'enseignement

Syllabus - Basics of semiconductor physics: energy bands; Fermi-Dirac distribution; difference betweek conductors, insulators, semi-conductors; doping
- Basics of lasers: black-body radiation; self-oscillation conditions; resonant cavities
- Semiconductor lasers: Bernard & Duraffourg condition; structures (Fabry-Perot, DFB); gain curve; evolution equations
- Electro-optical modulation: phase and Mach-Zehnder intensity modulators; electro-absorption
- Propagation in a dielectric waveguide: the optical fibre (modes, dispersion, attenuation)
- Optical signal detection and noise, amplified systems

Compétences à acquérir

List the basic concepts underlying opto-electronic devices and guided propagation
Explain their physical principles
Specify the characteristics of these devices that are critical to their use in optical transmission systems

Modalités d'organisation et de suivi

Professor in charge:
Cédric Ware, Associate Professor, TELECOM Paris

Langue

Anglais

Volume horaire

CM : 10h, TP : 6h, TD : 3h

Mode de contrôle des connaissances

Project (80%), Lab work scores (20%)

Refresher: Communication Networks

ECTS

2

Mots clés

Description du contenu de l'enseignement

Description General introduction to Networking, with a special focus on current network architectures and the specificities of optical networks.

Syllabus Global network architecture
IP networks
SDH networks
Mobile network architecture

Modalités d'organisation et de suivi

Professors in charge:
Mounia Lourdiane, Associate Professor, TELECOM SudParis
Cédric Ware, Associate Professor, TELECOM Paris

Langue

Anglais

Volume horaire

CM : 15h, TD : 3h

Mode de contrôle des connaissances

Final exam

Refresher: Digital Communications

ECTS

2

Mots clés

Description du contenu de l'enseignement

Course Objectives:

The objective of this refresher course is to provide the fundamentals tools of digital communications in the simplest case given by the Additive White Gaussian Noise channel.

Syllabus

• Additive White Gaussian Noise (AWGN) model
• Detection theory : MAP and ML detector
• Matched filter, Threshold detector
• Inter-Symbol Interference (ISI), Nyquist criterion
• Bit error rate, minimal distance, performance
• Block Forward Error Correcting codes (FEC), Coding gain

Compétences à acquérir

On completion of the course students should be able to:
• design an optimal coherent receiver
• know the relationship between fundamentals parameters (such as bandwidth, power, etc)
• understand the principle of an error correcting codes

Modalités d'organisation et de suivi

Professor in charge:
Ghaya Rekaya-Ben Othman, Professor, TELECOM Paris
Hadi Ghauch, Associate Professor, TELECOM Paris

Other teachers:
Antoine O. Berthet, Professor, CentraleSupélec

Langue

Anglais

Volume horaire

CM : 20h

Bibliographie, lectures recommandées

D. Tse, “Fundamentals of wireless communications”.
A. Goldsmith, “Wireless communications”.
J. Proakis, “Digital communications”.

Pré-requis obligatoires

Course Prerequisites:
• Introduction to digital communications (modulation BPSK, threshold detector)
• Introduction to statistics (random variable, random stationary process)

Mode de contrôle des connaissances

Final exam

Optoelectronic Devices

ECTS

4

Mots clés

Compétences à acquérir

- Derive laser oscillation equations and evolution equations for charge carriers and photons
- Explain the physical principles underlying semiconductor lasers
- List the common cavity structures used in laser design and describe their spectral response
- List the different classes of electro-optical modulators used in optical communication systems
- Explain each class' typical response in terms of linearity, bandwidth, phase-amplitude coupling
- Describe the main optoelectronic receiver types and their typical performances
- Derive wave guiding conditions in a dielectric waveguide, list mode categories, calculate the number of guided modes in a step-index planar structure
- Characterise the first few modes of an optical fibre; derive mode-coupling equations in a simple case (directional coupler or Bragg coupler)

- Acquire a strong knowledge of semiconductor laser dynamics; grasp nonlinear problematics and apply them to future communication systems
- Acquire knowledge of inter-sub-band devices. Explain the main differences between inter-band and inter-sub-band lasers. Acquire strong knowledge of applications, fabrication techniques, pros and cons of inter-sub-band devices

Modalités d'organisation et de suivi

Professors in charge:
Adel Bousseksou, Associate professor, Université Paris-Sud
Cédric Ware, Professor, TELECOM Paris

Langue

Anglais

Volume horaire

CM : 29h, TP : 4h, TD : 5h

Mode de contrôle des connaissances

Final exam, Lab work scores, Project

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Digital Information Processing

ECTS

3

Mots clés

Description du contenu de l'enseignement

Course Objectives:

The objectives of the course are to introduce the main solutions coming from digital communications and signal processing to improve the quality of the optical fiber based transmission.

Syllabus:

• Optical fiber model (CD, PMP, PDL, PDM, nonlinearity based Volterra series) with a digital communications point-of-view, Differences with wireless links
• Fundamental limits thorugh information theory tools: Shannon capacity and interpretation
• Detection theory (MAP, ML)
• Intersymbol interference mitigation
– Viterbi algorithm
– Linear and nonlinear equalization (ZF, MMSE, DFE) and application to optical fiber.
– What can you do with Channel State Information at the Transmitter (CSIT): predistorsion.
– OFDM and related detection
• Nonlinear processing based on inverse Volterra series and receiver architecture
• MIMO processing and polar-time coding
– Blind equalization (CMA) : block and adaptive version
– Polar-time coding and related metrics (rate, etc)
– Alamouti code, Blast, Golden code and related performance, code design criterion
– Multi-mode, multi-core based communications
– Modulation and Coding Scheme selection with CSIT or partial side information
• Frequency and Phase synchronization

Compétences à acquérir

On completion of the course students should be able to:
• understand the influence of design paramters
• understand the influence of fiber impairments on theoretical and practical performance
• understand the main techniques improving the performance and select them in a smart way

Modalités d'organisation et de suivi

Professor in charge:
Ghaya Rekaya-Ben Othman, Professor, TELECOM Paris

Other teachers:
Philippe Ciblat, Professor, TELECOM Paris

Langue

Anglais

Volume horaire
CM : 24h, TP : 3h, TD : 3h
Bibliographie, lectures recommandées
D. Tse, “Fundamentals of wireless communications”.
A. Goldsmith, “Wireless communications”.
J. Proakis, “Digital communications”.
Pré-requis obligatoires
Course Prerequisites:
• Refresher course on digital communications
• Course on point-to-point optical transmission systems (propagation part)
Mode de contrôle des connaissances
Final exam

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Error-Correcting Codes and Coded Modulations Applied to Optical Communications
ECTS
2
Mots clés
Description du contenu de l'enseignement
Course Objectives:
- Understand the basics of algebraic coding and decoding
- Understand the basics of modern coding theory and the associated probabilistic decoding
- Comprehend the performance evaluation techniques of error correcting codes

Syllabus

Chapter 1: Introduction to algebraic coding and finite fields (3h - lecture)
- Bloc codes: generator and parity matrices
- Syndrome decoding
- Families of algebraic block codes

Chapter 2: Finite fields
- Construction of Galois fields
- Operations in a Galois field (addition, multiplication, division)
- Minimal polynomial

Chapter 3: Algebraic codes and their decoding
- Cyclic codes and their encoding using the generating polynomial
- Classes of cyclic codes: BCH and Reed-Solomon codes
- Decoding algorithms: Peterson, Forney, Euclidian, Berlekamp-Massey
- Performance bounds

Chapter 4: Factor graphs and the sum-product algorithm
- Definition of a factor graph
- Computation of marginal probabilities using the sum-product algorithm
- Correctness of the sum-product algorithm on an acyclic graph
- Performances of the sum-product algorithm for decoding block codes

Chapter 5: LDPC codes: definition, construction and decoding
- Construction of regular LDPC codes
- Tanner graphs and the sum-product algorithm for decoding LDPC codes
- Complexity reduction techniques

Chapter 6: Performance analysis of LDPC codes
- Weight enumerating functions of ensembles of codes
- Upper bounds on the performances of ensembles of codes
- Convergence analysis of sum-product decoding (density evolution, EXIT charts)
- Codes optimization techniques for irregular and generalized LDPC codes

Compétences à acquérir
On completion of the course students should be able to:
- Parameterize an error correcting code according to Shannon’s channel coding theorem

- Implement a codec for algebraic or LDPC codes
- Evaluate the performances of error correcting codes in the context of optical communications

Modalités d'organisation et de suivi

Professors in charge:
Frederic Lehmann, Associate professor, TELECOM SudParis
Antoine O. Berthet, Professor, CentraleSupélec

Langue

Anglais

Volume horaire

CM : 15.5h, TP : 3h, TD : 1.5h

Bibliographie, lectures recommandées

- D.J.C. McKay, Information theory, inference and learning algorithms, Cambridge University Press, 2003.
- C. Heegard, S.B. Wicker, Turbo coding, Kluwer Academic Publishing, 1999.
- B. Vucetic, Turbo codes : principles and applications, Kluwer Academic Publishing, 2000.

Pré-requis obligatoires

M1 level course in Information Theory
M1 level course in Digital Communications

Mode de contrôle des connaissances

Written examination

Optical Information Propagation and Point-to-Point Transmission Systems

ECTS

3

Mots clés

Description du contenu de l'enseignement

Course Objectives:

From a capacity, distance and cost need, know how to design an adequate point-to-point transmission system, using high spectral efficiency modulation formats and counteracting long-haul optical propagation impairments.

Syllabus :

• Chapter 1 : Overview of an optical transmission system setup
Historical evolution of fiber optic transmission, growth of the need for capacity, review of technology breakthrough. Transmission setup from transmitter to receiver. Wavelength Division Multiplexing (WDM) principle. Optical amplification and Optical Signal-to-Noise Ratio (OSNR). Transmission system types from access to
submarine ones. Transmission quality criteria.

• Chapter 2 : Transmitter and Receiver design
Design of transmitters, laser sources, direct or external modulation, modulators setup and driving, modulation format implementations. Design of receivers, optical filter, photodiodes, noises, direct or coherent detection. OSNR receiver sensitivity for different modulation formats.

• Chapter 3 : Optical propagation in fibers
Physical constraints of single channel signal propagation, linear effects (loss, dispersion and Polarization Mode Dispersion) , nonlinear effects (Kerr, Raman, Brillouin). Physical constraints of WDM transmission, dispersion wavelength dependency, amplification bands, linear and nonlinear cross-talks. Additional cumulative Amplified Spontaneous
Emission (ASE) noise.Transmission modeling, temporal and spectral representation of signals, constellations, NonLinear Shrödinger Equation (NLSE) and numerical solving. Steps for designing transmission systems.

• Chapter 4 : Transverse view on new optical coherent transmission systems
Recall of the principle of coherent detection and complex modulation formats. Coherent mixer analysis and digital signal processing chain. Electronic dispersion compensation, PMD compensation and electronic polarization demultiplexing, phase and data recovery.

Compétences à acquérir
On completion of the course students should be able to:
• Objective 1 : Know and implement photonic devices and subsystems for transmissions.
• Objective 2 : Design optical transmitter and receiver for all kind of modulation formats.
• Objective 3 : Understand propagation signal impairments and know how to compensate or mitigate them.
• Objective 4 : Find the cost effective transmission system design that answers a capacity and distance transmission requirement.

Modalités d'organisation et de suivi
Professor in charge:
Yann Frignac, Professor, TELECOM SudParis

Other teachers:
Yves Jaouen, Professor, TELECOM Paris

Langue
Anglais

Volume horaire
CM : 18h, TP : 12h

Bibliographie, lectures recommandées
• Govind, P. Agrawal,"Nonlinear Fiber Optics", 4th edition, Academic Press, 2006.
• Govind, P. Agrawal,"Fiber Optic Systems", Academic Press, 2002.
• Ivan Kaminow et al., "Optical fiber communication", IIIA, IIIB, IVA, IVB, VA, VB, VIA, VIB, Academic Press, from 1988 to 2013.
• Irene and Michel Joindot, "Les Télécommunications par fibres optiques", Dunod, 1996.
• Zeno Toffano, "Optoélectronique : composants photoniques et fibres optiques", Ellipses.

Pré-requis obligatoires
Course Prerequisites:
• Waveguide optics, fibre optics and propagation modes.
• Light polarization, Jones, Stokes and Poincaré's sphere, optical propagation in anisotropic media.
• Devices for photonic systems : laser, modulators, mux, photoreceivers, optical amplification and filters.
• Digital communication, Additive White Gaussian Noise channel , Nyquist criterium, pulse shaping and match filtering, complex modulation formats and Bit Error Probability estimations.

Mode de contrôle des connaissances
Final Exam, Lab work scores

Advanced and Next-Generation Optical Transmission Systems

ECTS
2

Mots clés

Description du contenu de l'enseignement
Course Objectives:
Know the technologies that will supply extreme capacity demand while having the best energy efficiency. Advanced amplification techniques, future spatial multiplexing techniques, design and application of specialty fibers, tunable capacity transmitters and receivers. Acquire the ability of modeling transmission systems.

Syllabus:
• Chapter 1 : Spatially multiplexed transmission systems
Multicore and multimode fibers. Spatial multiplexer and EDFA technologies, MCF and FMF transmission systems. Coherent DSP technique adaptations. Cost per bit reduction and energy saving. Spatial and spectral information density.
• Chapter 2 : Advanced amplification schemes
Raman amplification. Parametric and Phase sensitive amplification. Semiconductor Optical Amplifiers (SOA).

• Chapter 3 : Next generation fibers
FMF and MCF fiber for coupled or uncoupled SDM transmissions. Design and applications of Photonic Bandgap Fibers.
• Chapter 4 : Elastic transmitter and receivers
Bit-rate adaptation for capacity demand, network routing constraints or energy saving. Superchannel concepts.
• Chapter 5 : Transmission systems modeling
Optical transmission system simulation project.

Compétences à acquérir

On completion of the course students should be able to:
• Objective 1 : Understanding the challenges of Spatial Division Multiplexing techniques, new large-band amplification schemes and new fiber types.
• Objective 2 : Modeling transmission systems
• Objective 3 : Optimize cost and energy saving for high bit rate transmission systems.

Modalités d'organisation et de suivi

Professor in charge:
Mansoor Yousefi, Associate professor, TELECOM Paris

Other teachers:
Yann Frignac, Professor, TELECOM SudParis

Langue

Anglais

Volume horaire

CM : 12h, TP : 9h

Pré-requis obligatoires

Course Prerequisites:
• Optical information propagation and point-to-point transmission system (M2 module)
• Matlab programming.
• Spatial and Fourier optics.

Mode de contrôle des connaissances

Final Exam

Optical Networks

ECTS

4

Mots clés

Description du contenu de l'enseignement

Syllabus

- Wavelength-Division Multiplexing: evolution to IP-over-WDM from IP/SDH/WDM transmissions
- Flexible and elastic optical networks
- Access/metropolitan network, WDM-PONs
- Fixed-mobile convergence
- Student Micro-project

Compétences à acquérir

- Explain operator networks' global architectures, and specific issues of core, access and metropolitan networks
- Design parts of a global network in situations with specific constraints (traffic type, range, interoperability...)
- Explain the network evolution techniques described in the course, identify situations where they are relevant

Modalités d'organisation et de suivi

Professors in charge:
Mounia Lourdiane, Associate professor, TELECOM SudParis
Cédric Ware, Associate professor, TELECOM Paris

Langue
Anglais
Volume horaire
CM : 9h, TP : 12h, TD : 9h, ProfessTraining : 10h
Mode de contrôle des connaissances
Final exam (60 %), lab work scores (20 %), project (20%)

Future Trends in Optical Networks
ECTS
2
Mots clés
Description du contenu de l'enseignement
Syllabus - Switching packets in optical networks: OBS, OPS and OSS technologies
- Core/metropolitan network, P-OADM technology
- New energy-aware transparent node architectures
- New optical domestic network architectures

Modalités d'organisation et de suivi
Professors in charge:
Mounia Lourdiane, Associate professor, TELECOM SudParis
Cédric Ware, Associate professor, TELECOM Paris
Langue
Anglais
Volume horaire
CM : 9h, TP : 3h, TD : 6h
Mode de contrôle des connaissances
Project

Photonic Systems Towards Other Applications
ECTS
3
Mots clés
Description du contenu de l'enseignement
Abstract
This course illustrates the diversity of photonic system applications. The course will be based on optical labworks (18h) and short courses/conferences dedicated to various applications (12h).

Syllabus
Optical Labworks contents:
- Optical Time Domain Reflectometry
- Optical Fiber Gyrometer
- Slow and Fast Line in optical Fiber
- Nonlinear optics : Second Harmonic Generation, Raman Scatering in an optical Fiber *Short courses and Conferences (indicative list):*
- Photonic crystal fibers
- LiFi Technology
- Advanced signal processing for sensor applications
- Optical sensors technology
- …

Modalités d'organisation et de suivi
Professor in charge:
Nicolas Dubreuil, Professor, IOGS

Langue
Anglais
Volume horaire
TP : 18h, ProfessTraining : 12h
Mode de contrôle des connaissances
Lab work scores

Fonction et intégration photonique
ECTS
3
Mots clés
Description du contenu de l'enseignement
Principes de fonctionnement et les technologies des dispositifs photoniques semi-conducteurs, dans une perspective d'intégration.

Compétences à acquérir
Principes de fonctionnement et les technologies des dispositifs photoniques semi-conducteurs, dans une perspective d'intégration.

Modalités d'organisation et de suivi

Henri Bénisty (IOGS)
Langue
Français
Volume horaire
CM : 30h
Mode de contrôle des connaissances
Session 1: EE ou EO Written or oral examination
Session 2: EE ou EO Written or oral examination

Nanophotonics
ECTS
3
Mots clés
Description du contenu de l'enseignement
Objective:
The objective of this module is to train students in the fields of nanophotonics and its applications through the study of the properties of light propagation in nanostructured environments as well as the benefits from nanostructures for optoelectronics.

Outline:
- Photonic integrated circuits
Properties of light waves
Guiding, photonic integrated circuits : building blocs
Example of application : silicon photonics
II - Propagation of light in nanostructured environments
Photonic crystals
Plasmonics
Metamaterial
III - Photonics active devices
Nanostructures for optoelectronics (quantum well, quantum dots, nanowires)

Compétences à acquérir
Abality to analyze and understand the challenges in photonics and nanophotonics. Be able to explain the basic phenomenom in the field

Modalités d'organisation et de suivi
Professor in charge:
Delphine Marris-Morini, Professor, Université Paris-Sud

Langue
Anglais

Volume horaire
CM : 24h, TP : 3h

Pré-requis obligatoires
Basic knowledge of electromagnetism and semiconductor device physics

Mode de contrôle des connaissances
written test + report on the lab session

Evaluation process :

The two semester do not compensate each other, average score has to be higher than 10/20 in each semester. Score for each teaching block has to be higher than 7/20 to validate credits. Weighting coefficients applied to the block in the average score calculation corresponds to the amount of the block credits.
The following table gives details on the evaluation method for each block.

Nom du UE	Semestres	ECTS	Heures	Modalités de contrôle de connaissances	Coefficients
S3 - Semestre 3					
Refresher: 2 elective courses to be chosen					
Refresher: Physics of Optoelectronic Devices	S3	2	19	Project (80%), Lab work scores (20%)	2
Refresher: Communication Networks	S3	2	18	Final exam	2
Refresher: Digital Communications	S3	2	20	Final exam	2
Core courses					
Optoelectronic Devices	S3	4	38	Final exam, Lab work scores, Project	4
Digital Information Processing	S3	3	30	Final exam	3
Error-Correcting Codes and Coded Modulations Applied to Optical Communications	S3	2	20	Written examination	2
Optical Information Propagation and Point-to-Point Transmission Systems	S3	3	30	Final Exam, Lab work scores	3
Advanced and Next-Generation Optical Transmission Systems	S3	2	21	Final Exam	2
Optical Networks	S3	4	40	Final exam (60 %), lab work scores (20 %), project (20%	4
Future Trends in Optical Networks	S3	2	18	Presentation	2
Photonic Systems Towards Other Applications	S3	3	30	Lab work scores	3
1 elective course to be chosen					
Fonction et intégration photonique	S3	3	30	Session 1 : EE ou EO Written or oral examination - Session 2 : EE ou EO Written or oral examinatior	3
Nanophotonics	S3	3	27	Written test + report on the lab session	3
TOTAUX ECTS S3	S3	30	294		
S4 - Semestre 4					
Internship	S4	30	0	4 months duration at the minimum. Report + defence	30
TOTAUX ECTS S4	S4	30	0		

END of DETAILED VERSIONS of each block contents
