SYLLABUS

1. Program information

1.1 Higher education institution	Technical University of Cluj-Napoca
1.2 Faculty	Faculty of Electronics, Telecommunications and Information Technology
1.3 Department	Communications
1.4 Field of study	Electronic engineering, telecommunications and information technologies
1.5 Cycle of study	Bachelor of Science
1.6 Study program / Qualification	Telecommunications technologies and systems/ Engineer
1.7 Form of education	IF – full-time education

2. Course information

2.1 Course title	Optoelectronic systems in telecommunications				Course code	53.10
2.2 Course coordinator	*Profesor dr ing. Galatus Ramona Voichita, email: ramona.galatus@bel.utcluj.ro*					
2.3 Seminar/ laboratory/ project/ practical activity coordinator	*Profesor dr ing. Galatus Ramona Voichita, email: ramona.galatus@bel.utcluj.ro*					
2.4 Year of study	4	2.5 Semester	2	2.6 Type of assessment		V
2.7 Course status	Formative category					DS
	Optionality					DOP

3. Estimated total time

3.1 Hours per week	4	of which:	3.2 Lecture	2	3.3 Seminar	0	3.3 Laboratory	2	3.3 Project	0	3.3 Practical training	0
3.4 Hours per semester	56	of which:	3.5 Lecture	28	3.6 Seminar	0	3.6 Laboratory	28	3.6 Project	0	3.3 Practical training	0

3.7 Time distribution (hours per semester) for individual study and assessment:	
(a) Assessment	16
(b) Study using textbook, course materials, bibliography, and notes	16
(c) Additional documentation in the library, on specialized electronic platforms, and in the field	14
(d) Preparation for seminars/laboratories, assignments, reports, portfolios and essays	18
(e) Tutoring	5
(f) Other activities	0

3.8 Total hours of individual study and assessment (sum of (3.7(a)...3.7(f))	69
3.9 Total hours per semester (3.4+3.8)	125
3.10 Number of credits	5.0

4. Prerequisites (where applicable)

4.1 curriculum	Optoelectronics
4.2 competencies	Understanding the fundamental principles of light propagation and the interaction of optical radiation with matter – Physics course. Ability to analyze and design basic electronic and optoelectronic circuits – Optoelectronics course.

5. Requirements (where applicable)

5.1. for the development of the lecture	Amphitheater TUCN
5.2. for the development of the seminar/ laboratory/ project	Labs BT105 and 328, Baritiu street, Cluj-Napoca

6. Specific competencies acquired

Professional competencies	C4. Design, implementation and operation of data, voice, video and multimedia services. This is based on the understanding and the application of fundamental concepts in telecommunications and transmission of information C4.1 Identification of the fundamental concepts regarding the transmission of information and analog and digital communications C4.2 Solving practical problems using general knowledge of multimedia techniques C4.3 Explanation and interpretation of the main requirements and specific approach techniques for data, voice, video, multimedia transmissions C4.4 Use of the main specific parameters in evaluations based on the concept of quality of service in communications C4.5 Development of simple communications services C4.6 Passing an examination regarding the main characteristics of the usual communications services C5. Selecting, installing, configuring and operating fixed or mobile telecommunications equipment. Equipping a site with usual telecommunications networks C5.1 Defining the principles of the main technologies for fixed and mobile telecommunications, through various transmission media C5.2 Explanation and interpretation of the technologies and of fundamental protocols for integrated fixed and mobile communications systems C5.3 Installation, configuration and exploiting of communications networks C5.4 Use of evaluation techniques and diagnostics for communications systems and equipment C5.5 Endowment with communications means of a location with a small/ medium degree of complexity C5.6 Solving an installation and maintenance problem for a communications system with low/ medium complexity

Professional competencies	C6. Solving specific problems of the broadband communications networks: propagation in different environment, circuits and equipment for high frequencies (microwaves and optical) C6.1 Identification/ definition/ presentation of the electromagnetic field laws addressing specific propagation and transmission issues, as well as of the specific circuits C6.2 Explaining the specific methods for implementation of the communications techniques C6.3 Solving practical problems using design methods of the microwave circuits, planning, coverage, selection and location of transmission and receiving equipment C6.4 Use of the main quality parameters and measurement techniques specific to the propagation and transmission media C6.5 Development of low/ medium complexity projects regarding the transmission and receiving equipment C6.6 Passing an examination regarding the principles of operation and use of the transmission and receiving equipment
Transversal competencies	CT1. Adhere to ethical principles, professional standards, and requirements related to safety, sustainability, and intellectual property in the design and implementation of optoelectronic communication systems. CT2. Collaborate effectively in multidisciplinary teams to develop and implement complex projects in the field of optoelectronic communication systems. CT3. Adapt to the rapid evolution of photonic technologies and continuously develop professional competencies through lifelong learning, the use of specialized software tools, consultation of scientific and technical literature, and participation in research and innovation activities.

7. Expected learning outcomes

Knowledge	- The student/graduate describes, identifies and summarizes elementary concepts and methods for signal acquisition, analysis and processing, implemented in systems with general-purpose processors or signal processors, as well as their application in concrete problems.
Skills	- The student/graduate designs low/medium-complexity functional blocks for digital signal analysis and processing and implements them on signal processors, microcontrollers or dedicated processors.
Responsibility and autonomy	- The student/graduate shows initiative and proactivity in updating professional, economic and organizational culture knowledge.

8. Course objectives (based on the grid of specific competencies acquired)

8.1 General objective of the course	To develop theoretical and practical competencies in the analysis, design, and evaluation of modern optical communication systems based on optical fibers and Photonic Integrated Circuits (PICs), through an understanding of the principles of light propagation, passive and active photonic components, Wavelength Division

	Multiplexing (WDM) technologies, and the design workflows specific to photonic integrated circuits.
8.2 Specific objectives	Upon successful completion of this course, students will be able to: explain the physical principles governing light propagation in optical fibers and optical waveguides; identify and characterize passive and active photonic components used in optical communication systems; analyze the operation of optical transmitters, receivers, and optical amplifiers, and evaluate their performance; design and dimension fiber-optic communication links using power budget analysis, time budget analysis, and key performance indicators such as Bit Error Rate (BER), Optical Signal-to-Noise Ratio (OSNR), and Q-factor; analyze the effects of attenuation, chromatic dispersion, and optical nonlinearities on the performance of optical communication systems; describe the architecture and operation of WDM/DWDM systems and modern optical networks; apply the concepts and design methodology of Photonic Integrated Circuits (PICs), including the use of Process Design Kits (PDKs), component libraries, and foundry-based fabrication workflows; interpret simulation results obtained using OptiWave OptiSystem (academic license) and experimental measurements of photonic components and optical communication systems; select appropriate technological solutions for applications in optical communications, data centers, photonic sensing, and quantum communications; use scientific literature and technical documentation to analyze and develop modern solutions in the field of optical communications. These objectives are intended to develop the knowledge and practical skills required for the design and evaluation of modern optical telecommunication systems, while preparing students to work with state-of-the-art technologies in integrated photonics and high-speed optical communications.

9. Contents

9.1 Lecture	**No. of hours**	**Teaching methods**	**Remarks**
1. Evolution of Optical Communications, Fundamentals of Geometrical Optics, and Light Propagation in Optical Fibers *Learning Objectives:* *1. Historical overview of optical communications. Ray optics, optical fibers and waveguides*	2		

9.1 Lecture	**No. of hours**	**Teaching methods**	**Remarks**
Frequency bands used in optical communications; Structure of single-mode (SM) and multimode (MM) optical fibers; Fundamentals of geometrical optics (ray-optics mathematical modeling); Light-ray propagation in step-index optical fibers; Modal dispersion; Graded-index optical fibers; Wavelength Division Multiplexing (WDM) and Spatial Division Multiplexing (SDM) using Multi-Mode Fibers (MMFs); Spatial Division Multiplexing using Multi-Core Fibers (MCFs).			
2. Optical Fibers, Dispersion, and Attenuation Phenomena *Learning Objectives:* *Manufacturing processes of optical fibers and fiber-optic cables; Optical fiber connectors and connector technologies; Installation of terrestrial and submarine fiber-optic cables; Specialty optical fibers (W-profile fibers, polarization-maintaining fibers, photonic crystal fibers (PCFs), multicore fibers (MCFs), etc.); Dispersion mechanisms (intramodal and intermodal dispersion); Optical attenuation mechanisms (Rayleigh scattering, Mie scattering, absorption, bending losses, etc.). Dispersion and attenuation compensation techniques and applications.*	2		
3. Nonlinear Effects in Optical Fiber Transmission *Learning Objectives: The Nonlinear Schrödinger Equation (NLSE).* *Kerr Nonlinearities-Self-Phase Modulation (SPM);Cross-Phase Modulation (XPM); Four-Wave Mixing (FWM).* *Scattering Nonlinearities Stimulated Raman Scattering (SRS); Stimulated Brillouin Scattering (SBS).* *Applications and compensation techniques for nonlinear effects.*	2		
Mid-Term Exam 1			
II. Optical Components			
4. **Optical Transmitters for Optical Communication Systems** *Learning Objectives:* *Operating principles of optical transmitters. Semiconductor materials for optical sources and light-emission mechanisms.* *Light-Emitting Diodes (LEDs) and laser diodes: structure, operating principles, and optical/electrical characteristics.* *Semiconductor laser types for telecommunications:* *Fabry–Perot (FP), Distributed Feedback (DFB), Distributed Bragg Reflector (DBR), Vertical-Cavity Surface-Emitting Lasers (VCSELs), External-Cavity Lasers (ECLs) and other examples.* *Static and dynamic characteristics:*	2		

9.1 Lecture	No. of hours	Teaching methods	Remarks
Optical output power, Quantum efficiency, Threshold current, Spectral linewidth, Wavelength stability, Temperature dependence. *Direct and external optical modulation techniques.*			
5. **Optical Receivers for Optical Communication Systems** *Learning Objectives:* *Operating principles of optical receivers and optical-to-electrical conversion.* *Photodetectors used in optical communications: PIN photodiodes; Avalanche Photodiodes (APDs)* *Device structure, operating principles, and performance characteristics. Responsivity, quantum efficiency, dark current, response time, and bandwidth.* *Noise mechanisms: Shot noise; Thermal noise; Amplifier noise* *Receiver sensitivity; Signal-to-noise ratio (SNR); Q-factor; Bit Error Rate (BER).* *Direct-detection receivers; Coherent receivers (heterodyne and homodyne).* *Eye diagrams and receiver performance evaluation.* *Effects of dispersion, noise, and nonlinearities on receiver performance.* *Receiver design criteria for modern high-capacity optical communication systems.*	2		
6. Optical Amplifiers *Learning Objectives:* *Fundamental concepts of optical amplification.* *Erbium-Doped Fiber Amplifiers (EDFAs); Raman amplifiers; Semiconductor Optical Amplifiers (SOAs).*	2		
7. **Passive Photonic Components I for Modern Optical Communication Systems** *Learning Objectives:* *Two-dimensional and three-dimensional waveguides.* *Optical couplers.* *Optical interferometers: Mach–Zehnder, Michelson, FP.* *Diffraction gratings. Optical attenuators.* *Optical isolators and circulators; Principle of nonreciprocity.* *Source protection. Signal routing* *Polarizers: Polarization beam splitters and combiners; Polarization controllers; Polarization-sensitive components.* *Optical filters. Fiber couplers. Optical splitters. Fiber-optic connectors. Additional passive components for optical signal conditioning and interconnection.*	2		

9.1 Lecture	No. of hours	Teaching methods	Remarks
8. Passive Photonic Components II *Learning Objectives:* *Spectral and WDM components:* *Fiber Bragg Gratings (FBGs)* *Arrayed Waveguide Gratings (AWGs)* *Optical Add-Drop Multiplexers (OADMs)* *Reconfigurable Optical Add-Drop Multiplexers (ROADMs)* *Microring resonators* *Photonic Integrated Circuit (PIC) building blocks*	2		
9. Active Photonic Components *Learning Objectives:* *Active integrated photonic devices implemented on:* *Silicon Photonics* *Indium Phosphide (InP)* *Silicon Nitride (SiN)*	2		
III. Optical Communication Systems			
10. WDM Systems and System Design *Learning Objectives:* *Transmission system capacity.* *Capacity limits of fiber-optic communication systems.* *Bandwidth limitation analysis.* *Optical system performance evaluation.* *Power budget analysis.* *Time budget analysis.* *BER, OSNR, and Q-factor evaluation.*	2		
11. Troubleshooting and Testing of Optical Fiber Communication Systems *Learning Objectives:* *Instrumentation for testing and troubleshooting:* *Optical Spectrum Analyzer (OSA).* *Optical power meters.* *Optical Time Domain Reflectometer (OTDR).* *Optical inspection microscopes.* *Fault localization and link characterization techniques.*	2		
12. Photonic Integrated Circuits (PIC): Design, PDKs, and Foundry Services *Learning Objectives:* *Introduction to Photonic Integrated Circuits (PICs) and their role in optical communications, data centers, photonic sensing, and quantum communications.* *Photonic integration platforms:* *Silicon-on-Insulator (SOI)*	2		

9.1 Lecture	**No. of hours**	**Teaching methods**	**Remarks**
Indium Phosphide (InP) *Silicon Nitride (SiN)* *Lithium Niobate ($LiNbO_3$)* *Hybrid photonic platforms* *Fundamental PIC building blocks (review).* *Complete PIC Design Flow:* *System specifications.* *Technology platform selection.* *Schematic design.* *Electromagnetic and circuit simulation.* *Design Rule Check (DRC).* *Layout Versus Schematic (LVS) verification.* *Photonic layout generation.* *Tape-out preparation.* ***Compact Models and Circuit Simulation*** *Standardized compact models.* *Parametric component libraries.* *Circuit-level simulation.* ***Process Design Kits (PDKs)*** *PDK concept and architecture.* *Parametric Cells (PCell).* *Design rules.* *Process limitations.* *Compact models.* *Standardized and reproducible photonic design.* *Examples from:* • *IMEC(https://www.imeciclink.com/en/asic-fabrication/photonic-ic-manufacturing)* • *AIM Photonics (https://www.aimphotonics.com)* • *CEA-Leti* • *Ligentec* • *Tower Semiconductor* • *GlobalFoundries* ***Foundry Ecosystem*** *Fabless manufacturing model.* *Multi-Project Wafer (MPW) services.* *Fabrication workflow.* *Project validation.* *Wafer fabrication.* *Wafer-level testing.* *Packaging.* *Device characterization.*			

9.1 Lecture	No. of hours	Teaching methods	Remarks
Manufacturing yield. *Process tolerances.* *Cost optimization.* ***Software Tools for PIC Design***			
13. Free-Space Optical Communications and Emerging Technologies ***Learning Objectives:*** *Fundamentals of Free-Space Optical (FSO) communication.* *Atmospheric propagation effects.* *Beam alignment and tracking.* *FSO applications.* *Hybrid RF/FSO systems.* *Emerging technologies for future optical communication networks.*	2		
14. Applications and Future Trends in Optical Telecommunications **Learning Objectives:** • *Case studies of modern optical communication systems.* • *Photonic interconnects for data centers.* • *Artificial intelligence in optical networking.* • *Space optical communications.* • *Quantum communications and Quantum Key Distribution (QKD).* • *Future directions in integrated photonics and optical networking.* *Course review*	2		
Final exam			

Fundamental references

Agrawal, G. P. *Fiber-Optic Communication Systems*, 5th Edition, John Wiley & Sons, Hoboken, NJ, USA, 2021.

Keiser, G. *Fiber Optic Communications*, Springer Nature Singapore Pte Ltd., Singapore, 2021. ISBN: 978-981-33-4664-2.

University Free Curricula Optiwave – Optiwave tool university license UTCN.

Complementary recferences

Curricula Southampton University UK: https://www.southampton.ac.uk/courses/2026-27/modules/opto6010?utm_source=chatgpt.com#overview

Le Nguyen Binh, "Optical Fiber Communications Systems: Theory and Practice with MATLAB® and Simulink® Models, CRC Press, 2014.

9.2 Seminar /laboratory /project /practical training	No. of hours	Teaching methods	Remarks
1. Introduction to Optical Instrumentation- Introduction to laboratory equipment, optical sources and detectors, laboratory safety regulations, and optical measurement techniques.	2	Demonstration and experimental laboratory activities, practical exercises, and teamwork.	
2. Optical Spectrum Analyzer (OSA) for Optical Communication Systems; Practical demonstration and individual hands-on measurements using a 3-channel visible WDM system.	2		
3. Optical Power Meter for Optical Communication Systems • Practical demonstration and individual characterization of optical fiber attenuation. • OptiWave OptiSystem Simulation: Analysis of a basic optical communication system.	2		
4. Optical Time-Domain Reflectometer (OTDR) • Practical demonstration and individual characterization of optical communication links and transmission phenomena using an OTDR. • OptiWave OptiSystem Simulation: Analysis of an optical communication system affected by chromatic dispersion.	2		
5. Indoor Fiber-Optic Link Installation • Assembly of a simple indoor optical communication link using an Optical Distribution Frame (ODF) and a fiber enclosure, including fusion splicing. • OptiWave OptiSystem Simulation: Analysis of an optical communication system with dispersion compensation.	2		
6. Optical Link Design Using a Power Budget Design of an optical communication link based on a predefined set of optical components.	2		
7. Optical Link Design Using a Power Budget Design of an optical communication link using optical components selected by the student from the Thorlabs catalog or other professional photonics catalogs.	2		
8. OptiWave OptiFDTD Simulation Design and simulation of an integrated optical coupler.	2		
9. OptiWave OptiFDTD Simulation Design and simulation of a passive optical interferometer.	2		
10. OptiWave OptiSystem Simulation Analysis and simulation of a Fiber Bragg Grating (FBG) optical filter.	2		
11. OptiWave OptiSystem Simulation Analysis and simulation of nonlinear effects in optical fiber communication systems.	2		
12. Bit Error Rate (BER) Analysis and Eye Diagram	2		

9.2 Seminar /laboratory /project /practical training	No. of hours	Teaching methods	Remarks
Performance evaluation using BER analyzers through simulation in OptiWave OptiSystem.			
13. Optical Interferometer Assembly Construction of an interferometer setup for understanding the operating principles of optical modulators.	2		
14. OptiWave WDM Phasar Design and simulation of an **Arrayed Waveguide Grating (AWG)**.	2		
Bibliography			

10. Alignment of the course contents with the expectations of the epistemic community, professional associations, and representative employers in the field related to the program

The course content and the teaching-learning-assessment methods are aligned with the current requirements of the Electronics, Telecommunications, and Information Technology Engineering field, considering the expectations of the academic and professional community, representative employers, as well as the national quality assurance standards in higher education. The course helps prepare students in line with employer expectations and the quality requirements set for engineering study programs.

11. Assessment

Activity type	**11.1 Assessment criteria**	**11.2 Assessment methods** (and type of assessment: continuous/ summative)	**11.3 Weight in final grade**
11.4 Lecture	Level of theoretical knowledge and practical competencies acquired	Mid-term essay examination and an individual assignment based on recent scientific literature (30%). Final written examination, including theoretical questions and problem-solving exercises (40%).	70%
11.5 Seminar/ Laboratory/ Project /Practical activity	Level of acquired knowledge and practical skills	Individual laboratory report submitted through **Microsoft Teams Assignments** (10%). Assessment of laboratory performance and	30%

		participation during practical sessions (20%).	

11.6 Minimum performance standard

To successfully complete the course, students must demonstrate a solid understanding of the fundamental concepts of optical communication systems and Photonic Integrated Circuits (PICs). They should be able to describe the operating principles of optical fibers, optical transmitters and receivers, optical amplifiers, passive and active photonic components, as well as the architecture of Wavelength Division Multiplexing (WDM) systems.

Students must be able to perform basic engineering calculations related to the optical power budget and the performance estimation of a fiber-optic communication link, identify the main attenuation, dispersion, and nonlinear effects, and explain their impact on optical signal transmission. Furthermore, they should understand the basic principles of Photonic Integrated Circuit (PIC) design, including the concepts of Process Design Kits (PDKs) and foundry-based manufacturing.

The minimum performance standard is achieved if the student obtains a minimum grade of 4.5/10 in the final assessment and demonstrates the ability to analyze and interpret the operation of a basic optical communication system while correctly applying the terminology and fundamental concepts of the field.

Completion date:	**Course coordinators**	**teaching rank, title First name LAST NAME**	**Signature**
23.06.2026	Lecture	*Prof Galatus Ramona Voichita,* Ph.D.	
	Applications	*Prof Galatus Ramona Voichita,* Ph.D.	

Approval of the Head of the Department coordinating the course, only if this differs from the department organizing the study program	Head of the Bases of Electronics Department Prof. Sorin HINTEA, Ph.D.

Date of approval by the Council of the Department of Communications 26.06.2026	Head of the Communications Department Prof. Virgil DOBROTĂ, Ph.D.
Date of approval by the Council of the Faculty of Electronics, Telecommunications and Information Technology 30.06.2026	Dean, Prof. Ovidiu-Aurel POP, Ph.D.