UNIVERSITÀ DEGLI STUDI DI PALERMO

DEPARTMENT	Ingegneria
ACADEMIC YEAR	2023/2024
MASTER'S DEGREE (MSC)	ELECTRONICS AND TELECOMMUNICATIONS ENGINEERING (FULLY ONLINE)
INTEGRATED COURSE	LASER AND OPTICAL COMMUNICATIONS C.I.
CODE	23291
MODULES	Yes
NUMBER OF MODULES	2
SCIENTIFIC SECTOR(S)	ING-INF/01
HEAD PROFESSOR(S)	MOSCA MAURO — Professore Associato — Univ. di PALERMO
OTHER PROFESSOR(S)	BUSACCA ALESSANDRO — Professore Ordinario — Univ. di PALERMO MOSCA MAURO — Professore Associato — Univ. di PALERMO
CREDITS	6
PROPAEDEUTICAL SUBJECTS	
MUTUALIZATION	
YEAR	1
TERM (SEMESTER)	1° semester
ATTENDANCE	Not mandatory
EVALUATION	Out of 30
TEACHER OFFICE HOURS	**BUSACCA ALESSANDRO** Monday 16:00 18:00 Laboratorio U 330 **MOSCA MAURO** Monday 18:00 19:00 IMPORTANTE! Il docente riceve sempre alla fine della lezione e per appuntamento. Giorno e orario sono stati inseriti in modo fittizio perche richiesti dal sistema!

DOCENTE: Prof. MAURO MOSCA

PREREQUISITES	Good knowledge of the analysis techniques for lumped parameters circuits for sinusoidal and pulsed regime, that students have acquired in the Electrotechnics course. Good knowledge of vector calculus and phasors. Basic knowledge of differential and integral calculus. Notions of Mathematics, Physics I and II. Solid-state electronics. Electronic Devices.
LEARNING OUTCOMES	Knowledge and comprehension capacity The course aims to provide the student with some advanced topics in the field of optoelectronic devices (light sources and photodetectors). It will be provided the basic theoretical principles, the characterization methodologies, and the applications of each device. Furthermore, the student will have acquired: • knowledge of propagation phenomenon in standard and special optical fibers; • in deep knowledge of the optical channel; • a good knowledge of the state of the art; • a particular comprehension of the use of electronics and electromagnetism in optical communications; • the useful tools for the design and test of an optical link; • a complete and thorough understanding of multiplexing, amplification, modulation, receiving, and transmission of optical signals; • will be aware of the multidisciplinary scientific context that embraces the fields of Electronics and Telecommunications. Ability to apply the acquired knowledge Thanks to a dynamic approach toward the applications of the devices, it is expected that the students are able to apply knowledge of what they have learned into practice. The student will be able to: • know the basic principles of photodetectors and optical sources (in particular, lasers); • recognize the optical modulation formats and the optical channel capacity; • apply the analytical tools of electromagnetism, electronics, electronic systems, and numerical transmissions to real problems related to optical communication; • design of optical communication channels; • measure and test optical communication systems; • develop problem-solving abilities in particular in the case of a network failure and in the design of an optical channel starting from the customer needs; • develop the ability to use their knowledge and understanding of models, systems and channels, and optical networks; • develop the ability to apply innovative methods and propose novel configurations on the basis of the state of the art; • develop the ability to use their knowledge, understanding, and creativity to design new and original systems, architectures, and components for optical communications. Making Judgements The aim of the course is not only to enhance knowledge of modern optoelectronic devices but also to give the students the methods and tools to characterize them. Students will thus be able to understand and justify the behavior of the devices. Upon completion of the course, they will also have acquired their own methodology for the analysis and characterization of the devices, in order to solve a problem as effectively as possible. For a typical optoelectronic system, they will be able to match the suitable devices. The student will be also able to: • develop their knowledge even in the absence of appropriate and complete technical specifications; • to identify, locate, quantify, and interpret through appropriate measures the optical and electro-optical quantities; • to design and independently evaluate, starting from the available budget and the requests of the client, an optical communication system; • to establish independently the components more appropriate with respect to the performance required by the customer; • to investigate the application of emerging technologies in the field of optical communications, in particular with reference to integrated optical components and special optical fiber; • develop the ability to integrate the know-how from photonics and telecommunications and to manage complexity; • have a deeper understanding of photonic techniques and their limits. Communication skills The student will be able to: • communicate and express the issues concerning optoelectronic devices and their applications; in particular, they will be able to sustain a debate or an interview on modern photonic sources (coherent and incoherent) and photodetectors; • acquire the ability to communicate issues concerning optical communications;

	• know the physical quantities and terminology of optical communications; • will be able to hold conversations on current issues affecting broadband communication; • use different methods to communicate effectively with colleagues and in particular with engineers during workshops and through oral presentations with or without the use of presentation software; • to discuss properly with optical communications specialists and with colleagues; to release technical guidelines; to manage groups of engineers and also communicate with non-experts; • to manage a team also not purely technical, and composed of competent persons in various disciplines at different levels both in a national context and in an international one; • to produce reports and disseminate scientific knowledge. Learning ability The student will be able to: • develop autonomous learning; • deal with problems related to the physical understanding and characterization of modern optoelectronic devices. This competence will allow them to access easily high-technical sectors of the industry, as well as doctoral courses in electronics and photonics; • carry out bibliographic research independently on topics of optical communications; • autonomously read a specialized document and understand it; • attend seminars and workshops and understand oral reports and proceedings; • acquire the ability to study and produce results autonomously; • extract important information in the field of optical communication and separate it from the useless one.
ASSESSMENT METHODS	Written exam The assessment of learning will be carried out through a final written exam. The written exam will focus on topics of optoelectronic devices and optical communications and will present open questions and questionnaires. The minimum grade needed to pass the exam is 18 out of 30. The objective of the final exam is to evaluate whether the student has a good knowledge and understanding of optical components and circuits, optical communication devices, and possible implementations in applications of interest to Electronics and Telecommunications Engineering. After the correction of the test, the Examination Board informs the student if the exam has been passed. If the exam is passed, the Commission assigns the student a grade based on the following evaluation criteria: a) level of knowledge of the topics covered by the written test, and autonomy in the ability to interconnect these topics with the others covered during the course (90% of the final grade); b) level achieved in the ability to write in the correct technical language (10% of the final grade). The exam is structured to verify the knowledge acquired, the processing capacity, the presentation ability, and the language properties of the student. The evaluation is based on the following criteria: a) excellent (30 - 30 cum laude): excellent knowledge of the topics, excellent language skills, good analytical skills, ability to apply knowledge to solve the proposed problems; b) very good (26 - 29): good command of the topics, full command of the language, ability to apply knowledge to solve the proposed problems; c) good (24 - 25): basic knowledge of the main topics, good command of the language, limited ability to autonomously apply the knowledge to the solution of the proposed problems; d) satisfactory (21 - 23): incomplete mastery of the main teaching topics, good command of the language, poor ability to autonomously apply the acquired knowledge; e) sufficient (18 - 20): minimum basic knowledge of the main teaching topics and technical language, very little or no ability to independently apply the acquired knowledge; f) insufficient: lack of minimal knowledge of the course contents. The e-tivities are based on the solution of exercises or questionnaires proposed at the end of each teaching module. E-tivities evaluate: - the ability to read and understand the research literature and technical standards related to the topics of the course; - the ability to reinterpret concepts and interdisciplinarity links, showing evidence to autonomously undertake further studies or professional activity.
TEACHING METHODS	Video lectures and e-tivities: 22 hours of video-lessons (asynchronous mode); 20 hours of e-tivities (virtual lab, exercises, questionnaires) The course is organized in 2 parts and 8 modules (4 modules for each part), each one including a set of video lectures (pre-recorded) and a set of e-tivity: More into details, the list of modules is the following one:

	1) Light, structures, and materials (5 hours of video lectures); 2) Photodetectors (2 hours of video lectures); 3) Light-emitting diodes (LEDs) (2 hours of video lectures); 4) Lasers (2 hours of video lectures); 5) Fiber optics (2 hours of video lectures); 6) Problems with the optical channel (3 hours of video lectures); 7) Optical transmitters and receivers (2 hours of video lectures); 8) Optical communication systems (4 hours of video lectures). For each module, we propose a set of exercises, questionnaires, and virtual laboratory experiences as additional learning activities, also devised to facilitate the self-assessment of the learning outcomes. We expect that each student will dedicate about 20 hours to these activities. Part of the activities is proposed as activities to be carried out autonomously by the students, while the other part will be supervised or led by the course tutor. More in detail, the e-tivities for each module (with or without a tutor) are the following ones: 1) Virtual lab of light properties (1 hour); 2) Questionnaire to self-evaluate knowledge and understanding of light nature, heterostructures, and optoelectronic materials (3 hours) 3) Questionnaire to self-evaluate knowledge and understanding of photodetectors (1 hour); 4) Questionnaire to self-evaluate knowledge and understanding of LEDs (1 hour); 5) Questionnaire to self-evaluate knowledge and understanding of lasers (1 hour); 6) Exercises on fiber-optic coupling (4 hours); 7) Exercises on fiber optical modes (4 hours); 8) Exercises on photodetectors and receivers (5 hours). The activities will be organized on the online learning platform, also exploiting discussion forums and interactive meetings. The overall number of hours for the individual study activities is estimated equal to additional 86 hours, and 22 hours for replaying the video lectures a second time.

MODULE
OPTICAL COMMUNICATIONS

Prof. ALESSANDRO BUSACCA

SUGGESTED BIBLIOGRAPHY

Teaching material (notes and slides) provided by the lecturer and the textbook_
G. P. Agrawal, Fiber-Optic Communication Systems, 2nd edition, Wiley
Interscience (1997) ISBN: 978-0470505113

AMBIT	20925-Attività formative affini o integrative
INDIVIDUAL STUDY (Hrs)	54
COURSE ACTIVITY (Hrs)	21

EDUCATIONAL OBJECTIVES OF THE MODULE

The course will provide a solid knowledge of devices and systems for optical fiber communications; the design criteria will be illustrated together with an evaluation of the optical fiber performances with a particular emphasis on wavelength division multiplexing (WDM) systems

SYLLABUS

Hrs	Frontal teaching
2	Fiber optics (2 hours of video lectures)
3	Propagation in the optical channel (3 hours of video lectures)
2	Optical transmitters and receivers (2 hours of video lectures)
4	Optical communication systems (4 hours of video lectures)

Hrs	Practice
3	Exercise on optical propagation.

MODULE OPTOELECTRONIC DEVICES *Prof. MAURO MOSCA*	
SUGGESTED BIBLIOGRAPHY	
- Teaching material (notes and slides) provided by the lecturer - J. Singh: Semiconductor Optoelectronics: Physics and technology, Mc-Graw-Hill, Inc. (1995) ISBN: 9780070576377 - S. M. Sze, M. K. Lee: Semiconductor Devices. Physics and Technology (3rd edition), John Wiley & Sons, Inc. (2012) ISBN: 978-0470537947 - C. W. Wilmsen, H. Temkin, L. A. Coldren: Vertical-Cavity Surface-Emitting Lasers: Design, Fabrication, Characterization, and Applications, Cambridge University Press (2001) ISBN: 9780521006293 - E. F. Schubert: Light-Emitting Diodes, Cambridge University Press (2012) ISBN: 9780511790546 - D. Sands: Diode lasers, IoP Publishing (2005) ISBN: 9780750307260 - M. Henini, M. Razeghi: Optoelectronic devices: III Nitrides, Elsevier (2005) ISBN: 9780080444260 - R. Karlicek • C.-C. Sun, G. Zissis, R. Ma (Eds.): Handbook of Advanced Lighting Technology (Springer International Publishing, Switzerland, 2017) ISBN: 9783319001753 - available free of charge on the UNIPA network of libraries - J. Li, G. Q. Zhang (Eds.): Light-Emitting Diodes - Materials, Processes, Devices, and Applications (Springer Nature, Switzerland, 2019) ISBN: 978-3319992105 - available free of charge on the UNIPA network of libraries - F. Träger (Ed.): Springer Handbook of Lasers and Optics (Springer Science +Business Media, LLC New York, 2007) ISBN: 978-3642194085 - available free of charge on the UNIPA network of libraries	
AMBIT	20925-Attività formative affini o integrative
INDIVIDUAL STUDY (Hrs)	54
COURSE ACTIVITY (Hrs)	21
EDUCATIONAL OBJECTIVES OF THE MODULE	
The course will provide a solid knowledge of the physical principles of modern optoelectronic devices, their applications, and characterization methodologies.	

SYLLABUS

Hrs	Frontal teaching
1	LIGHT - ITS NATURE AND ITS PROPERTIES: Electromagnetic spectrum. Speed of light and refractive index. Dispersion. Photon energy. Time and spatial coherence. Gratings. Monochromators. Optical activity. Electrooptic effect. Optical modulators
2	HETEROSTRUCTURES AND EPITAXY: Semiconductor crystal structure. The Miller index notation. The diamond, zinc-blende, and wurtzite semiconductor cells. Epitaxial-growth techniques: Chemical-Vapor Deposition (CVD), Metal-Organic CVD (MOCVD), Molecular-Beam Epitaxy (MBE). Semiconductor alloys. Heterostructure band diagrams: Anderson’s rule. Bandstructure engineering: heterojunctions and quantum wells. Semiconductor defects. Lattice-mismatched structures. Strained structures and dislocations. Buffer layers and virtual substrates.
2	MATERIALS FOR OPTOELECTRONIC DEVICES: Elements and alloys used in optoelectronics. Indirect gap materials and their transitions. The GaAsP system, GaP, GaAsP: N, and GaP: N. The AlGaAs / GaAs systems. The AlGaInP / GaAs systems. The silicon carbide (SiC). The GaN, AlGaN, InGaN, AlGaInN systems: problems, dislocations, methods to reduce the dislocations, ELOG growth. Spontaneous and piezoelectric polarization in nitrides. Thin and thick active regions in nitrides: Quantum Confined Stark Effect (QCSE). Ohmic contacts and polarization effects in nitrides. GaN p-doping. Recombination effects in dislocations. Theories to explain the high efficiency of nitrides. The "green-gap".
2	PHOTODETECTORS: Thermoelectric detectors. Bolometers. Pyroelectric detectors. Photomultipliers. Semiconductor-based photodetectors: Parameters, Photoconductors and related circuits, Photovoltaic detectors and related circuits. Multi-quantum well detectors. Junction detectors: p-n and p-i-n photodiodes, phototransistors. Avalanche photodiodes. Charge-Coupled Devices (CCDs).
2	LIGHT-EMITTING DIODES (LEDs): Injection Luminescence. Radiative recombination. Exciton recombination. Non-radiative recombination. Emission linewidth. LED construction. Light extraction. Radiation pattern. Electrical properties. LED drive circuitry. Efficiencies. ADVANCED STRUCTURES FOR HIGH-EFFICIENCY LEDs : Reasons that impede the fabrication of high-efficiency LEDs and their solutions. Double heterostructure. Quantum-wells. Separate confinement heterostructure: SCH and GRINSCH. Carrier loss. Electron-blocking layer. Light emission cone: extraction efficiencies. Optimization of geometries. Thick window layer and transparent substrate. Additional techniques to increase efficiency: TIP geometries, reflecting mirrors (epitaxial lift-off), rough surfaces (GaN etching, natural lithography), buried microreflectors, tapered structures (photoresist reflow technique).

2	LASERS: Emission and absorption of radiation. Stimulated emission. Einstein relations. Three- and four-levels lasers. Gain and optical feedback. Longitudinal modes and Doppler shift. Transverse modes. Argon laser. Nd:YAG laser. Semiconductor laser diode. Heterojunction lasers. VCSELs.

Hrs	**Practice**
9	Questionnaires on photodetectors, optical sources (LEDs and lasers)

Hrs	**Workshops**
1	Optics virtual laboratory