



OPTOELECTRONIC DEVICES	
Anno immatricolazione	2021/2022
Anno offerta	2021/2022
Normativa	DM270
SSD	ING-INF/01 (ELETTRONICA)
Dipartimento	DIPARTIMENTO DI INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE
Corso di studio	ELECTRONIC ENGINEERING
Curriculum	Photonics
Anno di corso	1°
Periodo didattico	Primo Semestre (27/09/2021 - 21/01/2022)
Crediti	9
Ore	74 ore di attività frontale
Lingua insegnamento	English
Tipo esame	SCRITTO
Docente	GIULIANI GUIDO (titolare) - 9 CFU
Prerequisiti	Knowledge of the advanced concepts in Physics and Optics, and in Electronics.
Obiettivi formativi	<p>Students will learn the physics, the basic principles of operation, the operating characteristics, the materials, the fabrication technology, the application fields, of electro-optic and photonic devices intended to generate or manipulate or detect light.</p> <p>By the end of the Course, students are expected to develop skills in the identification of the most suited electro-optic or photonic device for a given application or required performance.</p>
Programma e contenuti	<p>Part I - semiconductor light sources</p> <ul style="list-style-type: none">* World semiconductor laser market* Light generation from direct-band semiconductor materials: principle

- * LEDs (Light Emitting Diodes): materials; structures; operating characteristics; optoisolators; Solid-state lighting; RGB LED and White LED lighting systems; LEDs for displays and video projection; OLEDs; analysis of RGB LED datasheets
- * LUMENTILE European Project: Electronic Luminous tile
- * Introduction to LASER: the laser as an oscillator; optical amplification; threshold condition; pumping methods; oscillation frequency.
- * Semiconductor laser basics: structure; electrical and optical confinement; single- and double-heterostructure; optical waveguides (rib, ridge, buried)
- * Historical evolution of semiconductor lasers
- * Materials for semiconductor lasers: heterojunctions; lattice matching; III-V AlGaAs ternary system and InGaAsP quaternary system; II-VI material systems, active region: bulk, Multi-Quantum Well, Quantum Dots; optical gain
- * Technologies for semiconductor laser fabrication: epitaxial growth (Liquid Phase Epitaxy, Vapor Phase Epitaxy, Molecular Beam Epitaxy, Metal-Organic Chemical Vapor Deposition); growth of quantum dots; definition of optical waveguides; photolithography and electron beam lithography; masking; wet chemical etching and dry plasma etching; metallization; regrowth; details of transversal semiconductor lasers sections; bonding; cleaving; packaging
- * Operating characteristics of Fabry-Perot semiconductor lasers: light-current curve; emission spectrum; temperature effects (on threshold and emission wavelength); output beam characteristics (spot size, angular divergence, polarization); laboratory instrumentation for the characterization of semiconductor lasers; constant current electronic circuit; high-frequency direct current modulation; laser safety (at a glance); reliability (at a glance); analysis of semiconductor lasers datasheets
- * Simplified theory of the operation of semiconductor lasers: rate-equations; spontaneous recombination (radiative and non-radiative); stimulated recombination; waveguide losses; equivalent mirror losses; threshold current calculation; differential and quantum efficiency; frequency response; relaxation frequency; relative intensity noise
- * Experimental techniques for the characterization of semiconductor lasers: internal losses; optical spectrum; linewidth; relative intensity noise; modulation bandwidth; linewidth enhancement factor
- * Effects of optical backreflections in semiconductor lasers (at a glance): Lang-Kobayashi equations; weak feedback regime; coherence collapse; chaotic regime; master-slave injection and locking
- * Distributed-feedback (DFB) semiconductor lasers: optical Bragg gratings; fabrication techniques; types of gratings; $\pi/4$ - DFB lasers; performance; analysis of datasheets of commercial DFB lasers; DBR semiconductor lasers
- * VCSELs (vertical cavity surface-emitting lasers): principle; materials and fabrication techniques; light-current curve; optical spectrum; temperature effects; polarization; applications
- * VECSELs (vertical extended-cavity surface-emitting lasers), aka semiconductor disk lasers (at a glance)
- * Tunable semiconductor lasers: external cavity lasers (Littman and Littrow configurations); monolithic edge-emitting tunable lasers (DBR,

sampled-Grating DBR, Y-laser); VCSEL/MEMS tunable lasers; III-V on silicon lasers

- * High power semiconductor lasers (at a glance): stacked lasers; master oscillator + power amplifier (MOPA); VCSELs array

- * Semiconductor ring lasers (SRLs): structure; light-current characteristics; operating regimes (bidirectional and uni-directional) and directional bistability; application as all-optical set-reset flip-flop and toggle flip-flop; snail laser

- * Quantum cascade lasers (QCLs): importance of mid-infrared emission for applications; principle (inter-subband transitions, quantum cascade); optical waveguide; materials and fabrication technologies; operating characteristics; single-frequency DFB QCLs; the THz gap and THz QCLs; analysis of datasheets of commercial MIR QCLs

- * III-V on silicon lasers: introduction and motivation of silicon photonics; silicon photonics and III-V-on-silicon technologies; principle and performance of III-V-on-silicon Fabry-Perot lasers; III-V-on-silicon DFB lasers; III-V-on-silicon tunable and multi-wavelength lasers

- * New semiconductor lasers emitting at fancy wavelengths (at a glance): blue; green; yellow-orange

- * Mode-locked semiconductor lasers: mode-locking principle; saturable absorber; operating characteristics

- * SLEDs (Superluminescent Light Emitting Diodes) (at a glance)

- * Laboratory experimental sessions:

- o Detailed microscope analysis of commercial lasers (Fabry-Perot, VCSELs); measurement of P-I curve and spectral characteristics of semiconductor lasers of different types (Fabry-Perot, DFB, tunable external cavity laser)

Part II - Photodetectors

- * Classification of photodetectors

- * Photocathodes: photoemission process; types of photocathodes; spectral responsivity; vacuum phototubes

- * Photomultipliers: principle; structure; Single-Electron-Response (SER); charge gain; gain randomness; SER typical parameters; biasing circuits; applications: detection of optical weak signals, time measurements, photon counting, nuclear spectrometry

- * Photodiodes: internal photodetection process; materials and structures; performance; p-n junction photodiode; spectral sensitivity; I-V characteristics; equivalent circuit; frequency response (intrinsic and extrinsic cut-off); p-i-n photodiode; types of packages; photodiode circuits (basic circuit, trans-impedance)

- * Avalanche photodiodes: principle of avalanche multiplication; gain; SPAD (Single-Photon Avalanche Detector)

- * Photoconductors: principle and structure; materials; spectral response; use in basic circuit

- * Thermal detectors: principle; spectral response; equivalent circuit; types of temperature sensors; thermal imaging systems

- * Quantum and Thermal detection regimes: the bandwidth/sensitivity trade-off; signal-to-noise ratio; graph of signal-to-noise ratio vs. Pin

- * Coherent detection: principle; signal-to-noise ratio; phase-matching and phase coherence; applications

- * Imaging detectors: principle; serialization of 2D image signal; analog

	<p>and digital imaging;</p> <ul style="list-style-type: none"> * Vidicon: structure; principle of operation; image read-out; lag * CCD and CMOS image detectors: concept; working principle of CCD and methods for image read-out; * Photovoltaics and solar cells: importance of energy production from renewable sources; solar panels; solar cells (principle, electrical characteristics, V-I characteristics, solar spectrum and solar cell response, materials, efficiency, poly-crystalline silicon, concentration systems); organic photovoltaics * Laboratory experimental sessions: <ul style="list-style-type: none"> o Photodiode: basic circuit, external bias, output voltage, effect of load resistance, photovoltaic operation o Photoconductor: basic circuit, output voltage, effect of load resistance, speed response
Metodi didattici	<p>The Course is based on lectures that illustrate the physics, the working principles, the operating characteristics, and the fabrication technology of the considered devices.</p> <p>Tutorial laboratory sessions provide a "hands-on" experience where students are requested to experimentally measure the operating characteristics of a semiconductor laser and of semiconductor photodetectors. Laboratory sessions on photomultipliers, Vidicon camera imaging system, and advanced semiconductor laser are also foreseen.</p>
Testi di riferimento	<p>S. Donati, " Photodetectors. Devices, circuits and applications", Prentice Hall, 1999.</p> <p>Slides of the Course</p>
Modalità verifica apprendimento	<p>Written or oral test, with questions aiming at understanding which are the concepts acquired by the student and his/her ability to explain how the functional blocks of an optoelectronic device/instrument work. The minimum score to pass the exam is 18, the top one is 30 cum laude.</p>
Altre informazioni	
Obiettivi Agenda 2030 per lo sviluppo sostenibile	<p>\$Ibl legenda sviluppo sostenibile</p>