# Institute of Optoelectronics

Course proposals

Second degree studies in Optoelectronics

| | Subject | Lecturer's name | ECTS | Time account |
|---|---|---|---|---|
| 1. | Detection systems of optical radiation | Janusz Mikołajczyk | 4 | 40=14 L + 12 Lab + 4 Ex + 10 Sem |
| 2. | Optoelectronic measurements | Mirosław Nowakowski | 4 | 40=14 L+ 16 Ex + 10 Sem |
| 3. | Fiber optic technology | Mieczysław Szustakowski | 4 | 40=12 L + 12 Lab + 6 Ex + 10 Sem |
| 4. | Principles of optical design | Jacek Wojtanowski | 4 | 44=14 L + 4 Lab + 14 Ex + 12 Sem |
| 5. | Multispectral and hyperspectral systems | Mariusz Kastek | 4 | 40=14 L + 8 Lab + 8 Ex + 10 Sem |
| 6. | Functional photonic nanostructures | Piotr Nyga | 4 | 40=20 L + 8 Lab + 12 Sem |
| 7. | Optoelectronic devices supplying | Marcin Jakubaszek | 4 | 40=14 L + 12 Lab + 4 Ex + 10 Sem |
| 8. | Principles of lasers | Mirosław Szczurek | 4 | 40=20 L + 8 Lab + 12 Sem |
| 9. | Thermodetection systems | Grzegorz Bieszczad | 4 | 40=14 L + 12 Lab + 4 Ex + 10 Sem |
| 10. | Terahertz systems | Norbert Pałka | 4 | 40=14 L + 16 Lab +10 Sem |
| 11. | Spectroscopy and optical imaging in material research | Mirosław Kwaśny | 4 | 40=20 L + 12 Lab + 4 Ex + 4 Sem |
| 12. | Principles of laser remote sensing | Marek Zygmunt | 4 | 40=12 L + 4 Lab + 12 Ex + 12 Sem |
| 13. | Optoelectronic systems in environmental protection | Jarosław Młyńczak | 4 | 40=14 L + 8 Lab + 18 Sem |
| 14. | Photovoltaics | Beata Pietrzyk | 4 | 40=14 L + 8 Lab + 8 Ex + 10 Sem |
| 15. | Laser communication systems | Janusz Mikołajczyk | 4 | 40=14 L + 8 Lab + 8 Ex + 10 Sem |
| 16. | Optical spectroscopy techniques | Jacek Wojtas | 4 | 40=14 L + 12 Lab + 4 Ex + 10 Sem |
| 17. | Principles of quantum electronics | Jacek Kwiatkowski | 4 | 40=12 L + 6 Lab + 12 Ex + 10 Sem |
| 18. | Nanoimaging | Przemysław Wachulak | 4 | 40=24 L + 12 Lab + 4 Sem |
| 19. | Laser optics | Jan Jabczyński | 4 | 40=16 L + 8 Lab + 8 Ex + 8 Sem |
| 20. | Fundamentals of photonics | Krzysztof Kopczyński | 4 | 40=16 L + 8 Lab + 8 Ex + 8 Sem |
| 21. | Biometric authentication systems | Marcin Kowalski | 4 | 40=16L + 14 Lab + 10 Sem |

1. **Detection systems of optical radiation** ECTS: 4 (Janusz Mikołajczyk, BEng, PhD)

   40h = 14h Lectures + 12h Laboratories + 4h Exercises

Subject presents some of the fundamentals of the optical detection process. An idea of photoreceiver design is analyzed considering parameters of optical elements, detectors, preamplifiers and electronics. Sensitivities limit of direct detection techniques is identified. It includes also a description of the randomly fluctuating signals, or noise that appear at the output of any detection modules. Optimization procedures of photoreceiver parameters (SNR, gain, bandwidth) basing on some examples are discussed. Additionally, there are presented some advanced methods of signal analyses applied to increase SNR value. Application of some special devices (lock-in amplifier, boxcar amplifier, FFT signal analyzer) to improve properties of detection modules is also described.

2. **Optoelectronic measurements** ECTS: 4 (Mirosław Nowakowski, BEng, PhD)

   40h = 14h Lectures+ 16h Exercises + 10h Seminars

General rules for taking measurements. Optoelectronic measuring sensors, technical and metrological parameters. Measurement of optical radiation energy. Calibration of power and energy meters of optical radiation. Distance and speed measurements by laser. Measurements of wavelength and spectrum of optical radiation. Measurements of polarization and coherence of laser radiation. Interferometric measurements. Examples of optoelectronic measurement and registration systems

3. **Fiber optic technology** ECTS: 4 (Mieczysław Szustakowski, BEng, PhD, DSc, ProfTit)

   40h = 12h Lectures + 12h Laboratories + 6h Exercises + 10h Seminars

Semiconductor light sources. Principle of operation and construction of lasers, laser diodes, their coupling with optical fiber. Optical photodetectors. The principle of operation and the construction of optical detectors and receivers, their coupling with optical fiber. Digital optical links. Fiber optic telecommunication networks and systems, Optical analog links. Amplitude and interferometric sensors. Radio-fiber optic systems. Optical connections in free space.

4. **Principles of optical design** ECTS: 4 (Jacek Wojtanowski, BEng, PhD)

44h = 14h Lectures + 4h Laboratories + 14h Exercises + 12h Seminars

Introductory optical design course providing both the review of fundamental theoretical optical principles and variety of modern optical engineering techniques which are nowadays strongly related to the state-of-the-art specialized software. The scope of the course covers:
- review of optical elements (lens, mirror, aspherical elements, diffractive elements, optical filters),
- review of optical systems (imaging lenses, telescopes, microscopes, glasses, spectrometers),
- introduction to the theory of aberration and imaging (types of aberration, imaging quality criteria, diffraction limit),
- introduction to optimization methods of optical systems (local and global optimization, the concept of merit function, methods applied before the computer era, modern methods),
- introduction to specialized software for the design and optimization of optical solutions (implementation of optical system as a collection of optical surfaces and distances between them; defining the basic operating parameters - wavelength, aperture, field angles; analysis of the implemented optical system performance; system improvement through optimization; preparation of optical documentation).

5. **Multispectral and hyperspectral systems** ECTS: 4 (Mariusz Kastek, BEng, PhD)

40h = 14h Lectures + 12h Laboratories + 4h Exercises + 10h Seminars

The substantive scope of the subject includes introduction to the problems of construction and operation of multi-spectral and hyperspectral infrared imaging systems preceded by a reminder of theoretical foundations related to basic blackbody and real objects radiation, radiometric methods of temperature measurement, detection path analysis, analysis of atmospheric transmission in infrared spectrum, multi-spectral and hyperspectral data analysis methods. In the field of practical skills includes: the basics of multi-spectral and hyperspectral data analysis, operation and preparation of multi-spectral thermal imaging camera and infrared spectroradiometer for conducting measurements, analysis of the measurement situation, discussion of the specificity of measurements, measurement principles and measurement data analysis techniques.

6. **Functional photonic nanostructures** ECTS: 4 (Piotr Nyga, BEng, PhD)

40h = 20h Lectures + 8h Laboratories + 12h Seminars

This course scope is focused on three aspects of functional photonic nanostructures: fabrication techniques, characterization methods and applications. We will discuss: vacuum technology; physical and chemical methods of fabrication and modification of thin films and nanostructures, optical properties of

nanostructures; characterization techniques such as optical microscopy, electron microscopy: scanning and transmission, scanning tunnelling microscopy, atomic force microscopy; applications: plasmonics, metamaterials, thin film coatings, data storage, structural colour generation, metasurfaces, surface enhanced spectroscopies.

7. **Optoelectronic devices supplying** ECTS: 4 (Marcin Jakubaszek, BEng, MSc)

   40h = 14h Lectures + 12h Laboratories + 4h Exercises + 10h Seminars

This module is an advance theoretical and practical course of methods of optoelectronic elements and devices supplying. During this, students will get knowledge about typical solution in that subject and receive information of recent practical application.

8. **Principles of lasers** ECTS: 4 (Mirosław Szczurek, BEng, PhD)

   40h = 20h Lectures + 8h Laboratories + 12h Seminars

Introduction to lasers. Wave and quantum properties of electromagnetic radiation. Fundamentals of laser operation: active medium - energy levels, radiative and nonradiative transitions, laser resonator, laser operation control. Types of lasers. Laser systems. Laser – matter interaction and selected nonlinear effects.

9. **Thermodetection Systems** ECTS: 4 (Grzegorz Bieszczad, BEng, PhD)

   40h = 14h Lectures + 8h Laboratories + 8h Exercises + 10h Seminars

The aim of the module is to provide knowledge about various detection techniques based on phenomena occurring in the range of the electromagnetic infrared spectrum in the range from 3 to 12μm. In particular, detection methods will be discussed using matrix photon and bolometric infrared detectors. Methods of image processing specific to this type of detectors will be discussed. During laboratories and exercises, students will have the opportunity to independently test and modify methods of thermovision image processing and detection methods.

10. **Terahertz systems** ECTS: 4 (Norbert Pałka, BEng, PhD, DSc)

40h = 14h Lectures + 16h Laboratories + 8h Exercises + 10h Seminars

Introduction to THz radiation, semiconductor and photonic THz radiation sources, THz radiation detectors. Photoconductive switches. Time Domain Spectroscopy, Spectroscopic measurements by TDS. Imaging and tomography. THz imaging, sensors, waveguides, THz metamaterials. THz applications.

11. **Spectroscopy and optical imaging in material research** ECTS: 4 (Mirosław Kwaśny, BEng, PhD, DSc)

40h = 20 Lectures + 12 Laboratories + 4h Exercises + 4h Seminars

Principles of atomic and molecular spectroscopy. Classical theory of molecular rotations, vibrations and electronics form of energy. Instrumentation for optical spectroscopy- detectors, laser and incoherent sources of light, optics. Methods of atomic absorption and emission spectroscopy (ASA, ICP). Basics and applications of NMR and EPR. Spectroscopic study of optoelectronics, inorganics and biological materials. Methods of molecular spectroscopy (Raman, FTIR, UV-VIS, fluorescence) and imaging in chemistry and biology. Classical imaging in medicine: PET, NMR, X-ray, Doppler, OCT.

12. **Principles of laser remote sensing** ECTS: 4 (Marek Zygmunt, BEng, PhD)

40h = 12h Lectures + 4h Laboratories + 12h Exercises + 12h Seminars

The subject introduces the principles of remote sensing. The fundamentals of electro-magnetic radiation are explained, and its interactions with Earth's surface and atmosphere. The course goes on to examine lidars characteristics (elastic lidar measurement, differential absorption lidar for trace gas species detection, fluorescence and wind lidars). The module includes a large number of examples of applications of laser remote sensing.

13. **Optoelectronic systems in environmental protection** ECTS: 4 (Jarosław Młyńczak, BEng, PhD, DSc)

40h = 14h Lectures + 8h Laboratories + 18h Seminars

This module is an advance theoretical and practical course concerning optoelectronics system and devices used in environmental protection. During this module, students will get knowledge about typical solution in that subject and receive information of recent practical application.

14. **Photovoltaics** ECTS: 4 (Beata Pietrzyk, BEng, PhD)

40h = 14h Lectures + 8h Laboratories + 8 Exercises +10h Seminars

Module presents the fundamentals of photovoltaics technology and solar energy systems. The main aspects are solar radiation, solar illumination of the ground surface, photovoltaic effect in the p-n junction, parameters and characteristics of photovoltaic cells, installation components and configuration of photovoltaic systems for either mobile or stationary power sources.

15. **Laser communication systems** ECTS: 4 (Janusz Mikołajczyk, BEng, PhD)

40h = 14h Lectures +8h Laboratories + 8h Exercises + 10h Seminars

Subject presents the fundamentals of wireless optical communication systems (OWC). Analysis of OWC devices construction and their limitations are performed. Factors influencing on both range and data rate have been defined considering conditions of optical radiation propagation for different environments and for different physical phenomena. Significant parameters of OWC construction elements (lasers, detectors, optical systems, modulation and coding techniques) are determined to define properties of communication systems. The current state of both underwater and terrestrial communication technologies is also presented.

16. **Optical spectroscopy techniques** ECTS: 4 (Jacek Wojtas, BEng, PhD, DSc)

40h = 14h Lectures + 12h Laboratories + 4h Exercises + 10h Seminars

The module concerns the fundamentals of selected optical spectroscopy techniques used in gas detection. Basic information on absorption and scattering of optical radiation as well as principles of absorption spectroscopy of electromagnetic radiation in the range from long-wave infrared to ultraviolet light will be discussed. The course focuses on classic broadband and ultrasensitive techniques, spectroscopic instrumentation and some specific laser spectroscopy techniques. Special attention will be paid to laser absorption spectroscopy including tuneable and modulation techniques, multipass and cavity enhanced as well as photoacoustic spectroscopy. The module will provide the student with an in-depth knowledge of these topics so that spectroscopic methods can be successfully applied to the student’s research projects.

17. **Principles of quantum electronics** ECTS: 4 (Jacek Kwiatkowski, BEng, PhD, DSc)

40h = 12h Lectures + 6h Laboratories + 12h Exercises + 10h Seminars

Review of quantum mechanics. Operators and state vectors. The quantum postulates. The Heisenberg and Schrodinger equations. The uncertainty principles. Quantum harmonic oscillator. Equations for quantum laser systems. Principles of nonlinear optics. Theory of harmonic generation of light.

18. **Nanoimaging** ECTS: 4 (Przemysław Wachulak, BEng, PhD, DSc, ProfTit)

40h = 24h Lectures + 12h Laboratories + 4h Seminars

Introduction to nanoimaging. Nanotechnology and nanoimaging. Optical microscopy, superresolution microscopic techniques. STED microscopy. Short wavelength radiation (extreme ultraviolet, soft X-ray and hard X-ray). Nanoholography: Gabor, Fourier. Computer generated nanoholograms. Talbot imaging. Coherent diffraction lensless imaging. Ptychography. Full field nanoimaging. Nanotomography. Contact microscopy. Electron microscopy: scanning and transmission. Scanning tunneling microscopy. Atomic force microscopy.

19. **Laser optics** ECTS: 4 (Jan Jabczyński, BEng, PhD, DSc, ProfTit)

40h = 16h Lectures + 8h Laboratories + 8h Exercises + 8h Seminars

Introduction to ABCD method in geometrical and wave optics. Gaussian and multimode laser beam optics. Measurements of laser beam parameters. Principles of coherence theory and interferometry. Characteristics of typical laser sources: solid state lasers, fiber lasers, laser diodes, etc. Introduction to optical resonators. Fundamentals of laser beam shaping. Introduction to design of laser optics systems.

20. **Fundamentals of photonics** ECTS: 4 (Krzysztof Kopczyński, BEng, PhD, DSc)

40h = 16h Lectures + 8h Laboratories + 8h Exercises + 8h Seminars

Principles of geometrical optics and wave optics, propagation, diffraction and interference. Fundamental optical properties of solids, dispersion, polarization, scattering. Basic optical elements and devices: mirrors, prisms, lenses, collimators, monochromators. Waveguides and optical fibers. Basic optoelectronic devices: polarizers, retarders, filters, AO and EO modulators and switches. Characteristics (spatial, spectral, temporal) of typical optoelectronic sources: Laser Diodes, Fiber Lasers, LED’s. Fundamentals of nonlinear optics. Optical Detectors, principles, characteristics.

21. **Biometric authentication systems** ECTS: 4 (Marcin Kowalski , BEng, PhD)

40h = 16h Lectures + 14h Laboratories + 10h Seminars

The aim of the lectures is to introduce to biometrics as a method of authenticating persons, to present the issues of various biometric characteristics, construction and design of biometric authentication systems, with particular emphasis on access control systems and electronic identification data carriers. As a part of the course, students will be introduced to the principle of operation of popular biometric techniques and the construction of complex biometric systems.