General information		
Academic subject	Physics of Sensors and Laboratory of Spectroscopy	
Degree course	Physics	
Academic Year	2022-2023	
European Credit Transfer and Accumulation System (ECTS)	6	
Language	English	
Academic calendar (starting and ending date)	From September 2023 to December 2023	
Attendance	No	

Professor/ Lecturer	
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Tutoring (time and day)	Monday, 15:00 – 17:00; Wednesday, 16:00 – 18:00

Syllabus	
Learning Objectives	Absorption and Emission of Light. Widths and Profiles of Spectral Lines. Roto-Vibrational Spectroscopy. Spectroscopic Instrumentations. Doppler-Limited Absorption Laser Spectroscopic Techniques. Physics of Sensors. Laboratory Activities.
Course prerequisites	Background knowledge on quantum mechanics, statistical physics, and basic optics.
Contents	**Absorption and Emission of Light**. Discrete and Continuous Absorption and Emission Spectra. Transition Probabilities. Lifetimes. Spontaneous and Radiation-less Transitions. Semiclassical Description. Basic Equations. Weak-Field Approximation. Transition Probabilities with Broad-band Excitation. Phenomenological Inclusion of Decay Phenomena. Problems. **Widths and Profiles of Spectral Lines.** Natural Linewidth. Lorentzian Line Profile of the Emitted Radiation. Relation between Linewidth and Lifetime. Natural Linewidth of Absorbing Transitions. Doppler Width. Collision Broadening of Spectral Lines. Phenomenological Description. Theoretical Treatment of Anelastic Collisions. Saturation Broadening. Problems. **Roto-Vibrational Spectroscopy.** The Born-Oppenheimer Approximation. Rotational Spectroscopy. The rigid rotor. Linear Rotor. Transition Frequencies. Selection Rules. Intensity. Centrifugal Distortion. Symmetric Rotor Molecules. Prolate. Oblate. Spherical Rotor Molecules. Asymmetric Rotor Molecules. Vibrational Spectroscopy. The Harmonic Oscillator. Infrared Spectra. Electrical and Mechanical Anharmonicity. Roto-Vibrational Spectroscopy. P- R- and Q-branch. Branches Asymmetry. Polyatomic Molecules. Normal modes of vibrations. Group Vibrations. Basics on HITRAN Database. Example: Fundamental Band of Carbon Monoxide Molecule. **Spectroscopic Instrumentations.** Spectrographs and Monochromators. Figures of Merit. Speed of Spectrometer. Spectral Transmission. Spectral Resolving Power. Free Spectral Range. Prims Spectrometer. Grating Spectrometer. Interferometers. Basic Concepts. Michelson Interferometer. Mach-Zehnder Interferometer. Multiple-Beam Interference. Fabry-Perot Interferometer. Multilayer Dielectric Coatings. Problems. **Doppler-Limited Absorption Laser Spectroscopic Techniques**. Advantages of Laser Spectroscopy. Direct Absorption Spectroscopy. Modulation Techniques. Amplitude Modulation. Wavelength Modulation. Lock-in detection. Multipass Cell Absorption

	Spectroscopy. White Multipass Cell. Herriott Multipass Cell. Cavity Enhanced Absorption Spectroscopy. Longitudinal TEM00 cavity modes. Finesse and spectral bandwidth. Mode matching of the laser beam to the cavity. Cavity Ring-Down Absorption spectroscopy. Photoacoustic Spectroscopy. Light absorption and heat generation. Sound wave generation and detection. Quartz-enhanced photoacoustic spectroscopy. Quartz tuning forks: flexural modes. Pressure influence on damping and natural frequencies. Comparison of different gas detection techniques. Minimum absorption coefficient. Normalized noise equivalent absorption. **Physics of Sensors. Sensor Characteristics**. Transfer Function and Dynamic Range. Accuracy. Hysteresis. Saturation. Repeatability. Resolution. Dynamic Characteristics. Reliability. Calibration of a gas sensor. Physical Principles of Sensing. Piezoelectric Effect. Pyroelectric Effect. Seebeck Effect. Peltier Effect. **How to Prepare a Scientific Paper**. Overview. Structure and organization of a scientific paper. Introduction. Method. Results and discussion. Conclusions. Abstract. Scientific Style. Basics on HITRAN Database. Basics on Data Analysis with OriginLab. **Laboratory Activities**. Light-Current-Voltage Characterization of a Quantum Cascade Laser. Spectral Characterization of a Quantum Cascade Laser by using a FT-IR. Direct Absorption Spectroscopy. Wavelength Modulation Spectroscopy. Quartz-Enhanced Photoacoustic Spectroscopy.
Books and bibliography	W. Demtroder – Laser Spectroscopy – Basic Concepts and Instrumentation, Springer. J. Fraden – Handbook of Modern Sensors – Physics Designs and Applications, Springer.
Additional materials	Lecture notes at the website: http://polysense.poliba.it/index.php/physics-of-sensors-and-laboratory-of-spectroscopy/

Work schedule			
Total	Lectures	Hands on (Laboratory, working groups, seminars, field trips)	Out-of-class study hours/ Self-study hours
Hours			
	32	30	88
ECTS			
	4	2	

Teaching strategy	
	Lectures in the teaching room with the aid of a laptop and a projector. Laboratory activities supervised.

Expected learning outcomes	
Knowledge and understanding on:	The student will be able to: ○ account for spectroscopic methods in different energy intervals. ○ describe the most common components in spectroscopic equipment, ○ to more elaborately explain light-matter interaction in quantum mechanics.
Applying knowledge and understanding on:	○ apply basic principles of laser spectroscopic techniques, ○ practical skills to work with advanced experimental equipment in laboratory, ○ perform extended experimental investigations and critically analyses of the data, ○ write proper scientific reports.
Soft skills	• **Making informed judgments and choices** Given a specific problem and project in the field of optical measurements,

	students will be able to: ○ analyse the problem, ○ highlight the peculiar requirements and characteristics, ○ compare autonomously different choices in terms of spectroscopic techniques and system performance. • **Communicating knowledge and understanding** The students will be able to: ○ assess different spectroscopic methods, ○ assess magnitudes for many physical phenomena, ○ work practically with optical components and lasers, ○ access the state-of-the-art scientific literature of the reference topics, in terms of understanding the employed experimental methodologies and the related scientific results. • **Capacities to continue learning** ○ increase experience to work in a small group for a joint aim, ○ ability to present project that they have carried out in the form of a scientific paper, ○ integrate knowledge from English reference literature.

Assessment and feedback	
Methods of assessment	
Evaluation criteria	Capability to knowledge and discuss state-of-the-art spectroscopic techniques. Adequate comprehension and global knowledge of concepts and arguments described throughout the course.
Criteria for assessment and attribution of the final mark	
Additional information	Written report (50%), oral exam (50%)