



COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Applied Terahertz Physics (ATP)	

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinator: dr. Irmantas Kašalynas Other(s):	VU Faculty of Physics,

Study cycle	Type of the course unit (module)
second	compulsory

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
face-to-face	1 st (autumn) semester	Lithuanian (English)

Requirements for students	
Prerequisites: Solid state physics, Electrodynamics, Signal analysis.	Additional requirements (if any):

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
5	140	48	92

Purpose of the course unit (module): programme competences to be developed		
Learning of the interaction peculiarities of photons with electrons and phonons in matter in the THz frequency range, providing the basis for knowledge of THz physics, electronics and technology, application of the fundamental physics principles to the development of THz components, development of critical and analytical thinking.		
Learning outcomes of the course unit (module)	Teaching and learning methods	Assessment methods
Background knowledge that helps to understand the peculiarities of THz physics, aspects of THz photons interaction with matter, various applications in innovative fields including electronics, biology, medicine, materials science, communications.	Lectures, seminars, individual work.	Presentation and discussion during seminars, written exam.
Introduction to existing industrial and laboratory technologies used in production of THz sensors, emitters, passive components, development of abilities to choose necessary means for the production of THz components in practice.		
Presentation of new directions in THz physics, which will be useful in further studies.		
Development of abilities to analyze analytically and evaluate critically the information provided.		Presentation and discussions during seminars.

Content: breakdown of the topics	Contact hours							Self-study work: time and assignments	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work placement	Contact hours	Self-study hours	Assignments
1. Introduction. Study object, terms, main aims and questions.	2		1				3	4	Analysis of information provided at lectures, reading of literature, preparation of seminars.
2. Electromagnetic waves and their interaction with matter. Trigonometric and complex number description of waves, Maxwell's equations, material electrical conductivity and dielectric function, Drude model, conductors and dielectrics in the THz range.	2		1				3	4	Analysis of information provided at lectures, reading of literature, preparation of seminars.
3. Semiconductors. Band structure, quantum wells, hetero-structures, metal-semiconductor structures, conductivity quantization, carrier tunneling, phonons, plasmons, impurities, electrical contacts, carrier transport.	6		3				9	18	Analysis of information provided at lectures, reading of literature, preparation of seminars.
4. Wide bandgap semiconductors. Diamond, silicon carbide, gallium nitride and nitride heterostructures, 2D electrons, electron transport, tunneling, nonlinear carrier transport, negative differential conductivity, current-voltage, capacitance-voltage and noise characteristics.	6		3				9	18	Analysis of information provided at lectures, reading of literature, preparation of seminars.
5. THz emitters. Antennas, diffraction elements, amplitude and phase gratings, semiconductor switches, plasmonic structures, polariton structures, tunneling, IMPAT and Gunn diodes, varactors, quantum cascade lasers, single and multiple pixel emitters.	4		2				6	7	Analysis of information provided at lectures, reading of literature, preparation of seminars.
6. THz sensors. Principles of direct and indirect detection of THz photons in semiconductors, bipolar diodes, hetero-junction diodes, Schottky diodes, field effect transistors, high electron mobility transistors, micro-bolometers, sensor arrays.	4		2				6	12	Analysis of information provided at lectures, reading of literature, preparation of seminars.
7. THz systems. Basic principles and peculiarities of system design, integration of sensors and emitters with passive components, pulsed time domain systems, systems based on amplitude, frequency and phase modulation.	2		1				3	6	Analysis of information provided at lectures, reading of literature, preparation of seminars.
8. THz applications. Signal analysis, principles of 2D and 3D imaging, spectroscopic imaging, near field imaging, coding and transmission of information, innovative applications in security, material detection and identification systems, medicine, art, industry.	6		3				9	20	Analysis of information provided at lectures, reading of literature, preparation of seminars.
Total	32		16				48	92	

Assessment strategy	Weight, %	Deadline	Assessment criteria
Seminars	25	All semester	Ten points evaluation system. S₁ : points for presentation at the seminars: understanding of the topic, answers to the questions, ability to keep up discussion. S₂ : points for active participation in discussion during seminars. S=0.2×S₁+0.05×S₂
Exam	75	January	Exam consists of three questions: one main and two short questions, every question is evaluated using ten points system. The focus is on the student's ability to consistently and clearly formulate answers and justify his or her opinion. E₁ : answer to the main question. E₂, E₃ : answers to the short question. E=0.35×E₁+0.2×E₂+0.2×E₃

Author	Year of publication	Title	Issue of a periodical or volume of a publication	Publishing place and house or web link
Literature for main reading				
R. A. Lewis	2013	Terahertz Physics		https://www.cambridge.org/core/books/terahertz-physics/843DC9C4C5B44C7E3EBE2DEC52033395
D Saeedkia	2013	Handbook of Terahertz Technology for Imaging, Sensing and Communications		https://www.elsevier.com/books/handbook-of-terahertz-technology-for-imaging-sensing-and-communications/saeedkia/978-0-85709-235-9
Literature for additional reading				
V. Karpus	2002	Kristaliniis būvis. Kietųjų kūnų fizika		Vilnius; Ciklonas
A. Matulis	2001	Elektrodinamika		Vilnius; Ciklonas
Z. Vainoris	2004	Bangų elektronikos pagrindai		VG TU leidykla Technika
Perenzoni, Matteo, Paul, Douglas J. (Eds.)	2014	Physics and Applications of Terahertz Radiation		https://www.springer.com/br/book/9789400738362
Dimitris Pavlidis	2021	Fundamentals of Terahertz Devices and Applications		https://www.wiley.com/en-us/Fundamentals+of+Terahertz+Devices+and+Applications-p-9781119460718
P. YU, ,M. Cardona	2010	Fundamentals of Semiconductors: Physics and Materials Properties		https://www.springer.com/gp/book/9783642007095
D. K. Schroder	2005	Semiconductor Material and Device Characterization		https://onlinelibrary.wiley.com/doi/book/10.1002/0471749095
S. M. Sze, Y. Li, K.K. Ng	2021	Physics of Semiconductor Devices		https://www.wiley.com/en-us/Physics+of+Semiconductor+Devices%2C+4th+Edition-p-9781119429111
G. Carpintero, E. Garcia-Munoz, H. Hartnagel, S. Preu, A. Raisanen	2015	Semiconductor TeraHertz Technology: Devices and Systems at Room Temperature Operation		https://www.wiley.com/en-us/Semiconductor+TeraHertz+Technology%3A+Devices+and+Systems+at+Room+Temperature+Operation-p-9781118920398