COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Laser matter interaction	

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinator: assoc. prof. Vytautas Jukna **Other(s):**	Laser Research Center, Faculty of Physics

Study cycle	Type of the course unit (module)
Second (master program)	Compulsory

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
	Autumn semester	Lithuanian

Requirements for students	
Prerequisites: Courses of Optics.	**Additional requirements (if any):** Solid-state physics, laser physics, electrodynamics.

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
5	140	52	88

Purpose of the course unit (module): programme competences to be developed		
This course explores the physics of the interaction between laser radiation and matter; models of interaction between light and material are described; processes of electromagnetic radiation absorption, changes in material properties under the influence of light, destructive and thermal effects of radiation are discussed; the physics of the interaction between extremely intense optical fields and the matter is reviewed. Many experimental techniques, schemes, and equipment to measure material optical properties and their change due to laser radiation will be presented.		
Learning outcomes of the course unit (module)	**Teaching and learning methods**	**Assessment methods**
This course aims to provide students with a comprehensive understanding of the physics fundamentals of laser radiation and material interactions and to broaden their knowledge of the potential uses of laser radiation. The complex processes will be analyzed by employing mathematical models and numerical tools with a critical interpretation of the results. Forefront applications of laser-matter interactions will be explored during seminars, providing students a way to master diverse methods to search for information and communicate the findings. The acquired knowledge will enable them to understand specific disciplines of laser technologies, allow them to integrate knowledge to develop forefront complex photonic systems, and will let to undertake further independent study of specialized literature.	Lectures, seminars	Exam

Content: breakdown of the topics	Contact hours							Self-study work: time and assignments	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship/work	**Contact hours**	**Self-study hours**	**Assignments**
1. **Optical properties of materials.** Classification of optical properties. Optical coefficients. Complex refractive index and dielectric permittivity. Optical materials. Characteristic optical properties of solid-state materials.	2		1				**3**	**3**	Reading of lecture notes and textbooks.
2. **Microscopic models.** Free and forced oscillator models. Lorenz model of the dielectric materials. Refractive index dispersion modes. Drudes-Lorenz model of metal. Individual cases. Optical parameters of real materials.	2		1				**3**	**3**	Reading of lecture notes and textbooks.
3. **Linear absorption.** Absorption laws. Absorption in quantum viewpoint. Fundamental interband and lattice absorption. Direct and indirect optical absorption. Absorption by free electrons	2		1				**3**	**3**	Reading of lecture notes and textbooks.
4. **Excitons.** Free excitons. Absorption of excitons. Free excitons in external electric, magnetic fields. Properties of high-density free excitons, exciton drops, Bose-Einstein condensate. Frenkel excitons.	2		1				**3**	**3**	Reading of lecture notes and textbooks.
5. **Luminescence.** Radiation of light in solid-state materials. Interband luminescence in direct and indirect bandgap materials. Photoluminescence. Excitation and relaxation. Einstein coefficients. A case of low density of charges. A degenerate case. Photoluminescence spectroscopy. Electroluminescence.	2		1				**3**	**3**	Reading of lecture notes and textbooks.
6. Free electrons. Plasma reflection. Conductivity of free carriers. Metals. Drude model. Inter-band absorption of metals. Semiconductors with impurities. Impurity absorption. Plasmons.	2		1				**3**	**3**	Reading of lecture notes and textbooks.
7. Interaction of an electron with an electromagnetic field. Equation of free electron motion in an oscillating field. Electron energy increase in electromagnetic field. Collisions between particles. Radiation and absorption by change of velocity. Electron energy loss due to collisions. Electron motion in a heterogeneous field. Electron acceleration by interaction of electromagnetic radiation with plasma.	4		2				**6**	**6**	Reading of lecture notes and textbooks.
8. Interaction of atoms with electromagnetic field. Atomic Oscillator. Resonant processes in the atom, absorption and radiation. Saturation effect in a two-level atom system. Ionization of an atom.	4		1				**5**	**5**	Reading of lecture notes and textbooks.
9. Strong field. Nonperturbative case. Optical field ionization. Over-barrier ionization. Generation of higher harmonics. Attosecond pulses.	2		1				**3**	**3**	Reading of lecture notes and textbooks.
10. Interaction dynamics. Excitation, relaxation. Characteristic times of unbalanced processes.	2		1				**3**	**3**	Reading of lecture notes and textbooks.

Thermalization. Electron and lattice dynamics. Recombination, diffusion.									
11. Thermal effects. Thermal processes. Thermal conductivity equation. Characteristic parameters. Heating by laser radiation. Thermoelastic phenomena. Phase transformations. Technological applications.	4		1				**5**	**5**	Reading of lecture notes and textbooks.
12. Ultra-fast processes. Impact of pulse duration on interactions. Non-thermal interaction mechanisms. Two temperature model. Ultra-fast material ablation. Modification by ultrashort pulses.	2		1				**3**	**3**	Reading of lecture notes and textbooks.
13. Optical breakdown. breakdown generation process. The model of breakdown via avalanche ionization. Critical plasma density. Breakdown threshold. Laser spark. Breakdown propagation.	2		1				**3**	**3**	Reading of lecture notes and textbooks.
14. Damage of materials. Damage in solid-state materials. Damage of ideal and heterogeneous media. Damage threshold. Statistical concept of damage. Accumulation effect.	2		1				**3**	**3**	Reading of lecture notes and textbooks.
15. Light pressure. The nature of pressure in classical and quantum viewpoints. The pulse of light. Resonant light pressure. Optical refrigeration. Non-resonant light pressure. Light pressure in a heterogeneous field.	2		1				**3**	**3**	Reading of lecture notes and textbooks.
16. **Preparation for the exam**								**36**	
	36		16				**52**	**88**	

Assessment strategy	Weigh t,%	Deadline	Assessment criteria
Exam	100	By the end of the course	Exam in written form, 4 questions from the whole course. The mark definitions: <5 below threshold 5 – weak 6 – satisfactory 7 – average 8 – good 9 – very good 10 – excellent

Author	Year of public ation	Title	Issue of a periodical or volume of a publication	Publishing place and house or web link
Compulsory reading				
M. Fox	2012	Optical Properties of Solids, 2nd ed.		Oxford University Press (Available at VU library as 539.2/Fo64)
J. Weiner, F. Nunes	2017	Light-matter interaction : physics and engineering at the nanoscale, 2nd ed.		Oxford University Press (Full text is available at https://virtualibiblioteka.vu.lt from VU network))
M. von Allmen, A. Blatter	1998	Laser-Beam Interactions with Materials: Physical principles and Applications, 2nd updated ed. Springer Series in Materials Sciences,		Springer-Verlag Berlin, (Available at VU library as 621.373/Al142; full text is also available at https://virtualibiblioteka.vu.lt from VU network)
D. Bäuerle	2000	Laser Processing and Chemistry.		Springer-Verlag Berlin

				(Available at VU library as 621.373/Ba589)
Optional reading				
W.M. Steen, K. Watkins	2003	Laser Material Processing		Springer-Verlag UK
J. Ion	2005	Laser Processing Of Engineering Materials: Principles, Procedure And Industrial Application		Butterworth-Heinemann
R.M. Wood	1993	Laser-Induced Damage of Optical Materials		Taylor & Francis Group
P. Gibbon	2005	Short Pulse Laser Interactions with Matter: An Introduction		Imperial College Press
Н.Б. Делоне	1989	Взаимодействие лазерного излучения с веществом		М.: Наука