COURSE UNIT DESCRIPTION

Course unit title	Code
Technologies of Optical and Laser Elements	

Annotation
The course is dedicated for students, seeking master degree in Laser Technology program at the Faculty of Physics of Vilnius University or doctoral degree to acquire skills and special knowledge related to the components of laser devices - optical elements. The course reviews the basic properties of optical elements: their material properties, production and characterization methods. Methods of synthesis for both crystalline and glassy solids are overviewed including their rough and precise machining (shaping of optical surfaces). Much attention is paid also to the optical thin films and related deposition technologies. Methodologies for characterization of such elements are reviewed. The methods of production technology optimization are discussed while introducing design of experiments.

Lecturer(s)	Department, Faculty
Coordinating: Doc. dr. Andrius Melninkaitis **Other:** Doc. dr. Tomas Tolenis j. asist. E. Atkočaitis (laboratory works)	Faculty of Physics, Laser Research Center

Study cycle	Type of the course unit
Second (Master)	Compulsory

Mode of delivery	Semester or period when it is delivered	Language of instruction
Auditory and/or distant	Autumn semester	Lithuanian or English

Requisites	
Prerequisites: Optics, Laser Physics Courses	**Co-requisites (if relevant):** English

Number of ECTS credits allocated	Student's workload (total)	Contact hours	Individual work
5	134	48	86

Purpose of the course unit: programme competences to be developed		
Acquired practical and theoretical knowledge about the operation, properties and applications of laser optical elements: - production technologies (synthesis, formation of optical surfaces, coating; principles of functional optical elements); - quality parameters and their characterization methods; - optimization of technological parameters.		
Learning outcomes of the course unit	**Teaching and learning methods**	**Assessment methods**
After the course the students are expected to know: • classical optical production technology of laser elements (including production bulk materials and thin film optical coatings); • parameters describing the quality of optical elements and their evaluation methods (optical resistance, cosmetic surface quality, absorption and scattering losses); • how to select suitable optical elements for the intended application;	The theoretical part is presented in the lectures. Excursion – getting familiar with optical production facilities. Individual work: preparation and presentation of seminar materials;	Total score consists of evaluation of written exam answers, evaluation of creativity task and presentation of individually prepared topic for seminar (from list of topics) (Only upon successful completion and defense for laboratory works)

• principles of production technology optimization; • global trends in optics development and related production technologies.		
Optical element coating technology and quality description	Practical skills are acquired during the laboratory work.	Defense of laboratory work results
Feasibility study of optical elements: "100 + 100" ways of using optical elements	Individual work	Collection and sorting of ideas on the use of optical elements

Course content: breakdown of the topics	**Contact hours**							**Individual work: time and assignments**	
	Lectures	Tutorials	Seminars	Workshops	Laboratory work	Internship/work	**Contact hours,**	**Individual work**	**Assignments**
1. Introduction and general knowledge: - the optical elements and their most use cases (*creativity task*); - overview and classification of optical phenomena; - complex refractive index and dielectric constants.	4						4	20	Study of lecture material and related textbooks; Creativity challenge: feasibility study of optical elements and their applications;
2. Optical materials: spectral properties. - dielectrics in solid state: features, nature of colors and Lorentz model; - metals and their optical properties: Drude model;	6						**6**	8	Study of lecture material and related textbooks; Numerical simulation of spectral response;
3. Optical materials: synthesis and doping. - optical glasses: raw materials and production technology; - doping with rare metal ions and nanoparticles; - growth of optical crystals: Vernuil, Czochralski, Bridgeman, Stepanov, Float zone methods; Rapid growth from a water solution of salt; - molecular materials – optical plastics and their spectral properties.	6						**6**	6	Study of lecture material and related textbooks;
4. Optical coatings: classical deposition technologies for forming of optical layers; Physical Vapor Deposition (PVD) Methods: - thermal-resistive evaporation; - electron beam evaporation; Modifications: - glancing angle deposition (GLAD): anisotropic and porous coatings. - ion assisted evaporation; Sputtering methods: - magnetron sputtering (DC, RF); - ion beam sputtering (IBS); Chemical deposition processes: - Chemical Vapor Deposition (CVD) - Atomic Layer Coating (ALD); Deposition from liquids: - sol-gel coatings.	2					4	**6**	**2**	Study of lecture material and related textbooks; Practice/internship at FTMC OCL laboratory: getting familiar with coating deposition apparatus; (In case of acceptance, also visiting one of optics factories in Vilnius)

5. Optical coatings: the most popular coating designs and their spectral responses. - specification of required spectral properties, optical coating design optimization methods; - Optical thickness units and classical optical coating structures; - antireflection AR coatings (1V, 2V); - filters: broadband, "cut-off", narrowband; - high-reflectivity mirrors (metallic, dielectric); - beam splitters: for intensity, spectral dividers (dichroic filters), polarizers; - dispersive coatings (chipped mirrors); - types and properties of sculptural coatings.	2						**2**	**2**	Study of lecture material and related textbooks;
6. Optical coatings: selected compartments and related technologies (*also available as topics for seminars*): - clean room environment; - control methods of growing layer thickness during the deposition process; - vacuum pumps (types: advantages and shortcomings) - cleaning and transportation of optical substrates; - methods of mixing materials during evaporation (optical properties and models of mixtures); - deposition of extremely large optical elements: planetary dome, shading methods; - the most popular coating materials and working gases;	2						**2**	**2**	Study of lecture material and related textbooks;
7. Basic requirements for the quality of optical elements and standardized characterization methods for of optical materials. - losses of absorption, scattering and reflection, transmission; - estimation of surface shape deviations and roughness; - scratch and dig method for cosmetic surface quality assessment; - optical resistance and damage threshold;	6						**6**	**6**	Study of lecture material and related textbooks;
8. Introduction to optimization of production process. Design of experiment: variable types, response function model, full and fractional factorial designs, screening and optimization strategies, blocking.	2						**2**	**2**	Study of lecture material and related textbooks;
9. Laboratory work. 1. Investigation of optical resistance. 2. Investigation of optical scattering losses 3. Investigation of absorption losses					12		12	12	Reading lecture materials and textbooks, preparing for laboratory work and preparation of the report on the results.
10. Seminars. (*suggested seminar topics*) **Spatial, temporal and spectral modulators and specialized optical elements**: 1. electro-optical modulators and switches; 2. galvanometric scanners; 3. liquid crystal optical elements and SLM technology; 4. acousto-optical modulators and scanners; 5. micromechanical optical elements – spatial light modulators - M(O)EMS; 6. adaptive optical elements; 7. diffractive optical elements and their lithographic production methods;			8				8	20	Individual work: collection of pertinent information, preparation and presentation (20 min), discussion during the seminar;

8. volume Berg gratings and related optical elements (VBG technology); 9. laser beam (direction) stabilizers; 10. Faraday isolators; 11. saturable absorbers (photochromic crystals and SESAM coatings); 12. Ultrashort pulse stretchers and compressors (prisms and gratings) **Optical materials: methods of shaping and finishing of optical surfaces and bonding of optical surfaces;** 13. mechanical processing of glass and crystals: cutting, grinding, polishing; subsurface damage, Beilby layer; 14. diamond turning, production technologies of aspherical and free-form optical elements; 15. corrective polishing and surface etching with ion beams; 16. chemical etching of optical surfaces; 17. laser polishing; 18. nanotexturing of optical surfaces; 19. molding and stamping of plastic and glass elements; 20. optical contact; 21. bonding of optical surfaces using specialized materials;									
Total									

Assessment strategy	Weight %	Deadline	Assessment criteria
Exam	80	During the exam session	Exam in writing: 6 questions from the whole course. The overall grade of the exam is from 0 to 8 points, obtained by summing up the individual assessments for the answers to the questions.
Seminar presentation from selected list of topics	10	During the semester	Prepared presentation with answers to questions and discussion. Assessment in a 10-point system, which is up to 1 point in total with the exam results.
List of collected ideas for the use of optics	10	During the semester	Creativity task: optics scrapbook - a list of 200 ideas for the possible use of optics is prepared, of which at least 100 are optical schemes and the other 100 ideas are related to optics use in general. Assessment in a 10-point system, which is up to 1 point in total with the exam results.
Laboratory work - description and defense of work results	0	During the semester	3 laboratory works mandatory, including defense of each work: **upon completion the right to take the exam is granted**
Total	100		The total score is rounded up: <5 points - not passed (insufficient) 5 points - weak 6 points - satisfactory 7 points - average 8 points - good 9 points - very good 10 points - excellent

Author	Publishing year	Title	Issue of a periodical or volume of a publication; pages	Publishing house or internet site
Required reading				
M.Fox	2005	Optical Properties of Solids		New York; Oxford University Press
J.H.Simmons, K.S.Potter	2000	Optical materials		San Diego, London; Academic Press

Eds. H.Bach, N.Neuroth	1998	The Properties of Optical Glass		Berlin; Springer-Verlag
Eds. N.Kaiser, H.K.Pulker	2002	Optical Interference Coatings		Springer
Recommended reading				
D. Ristau	2014	Laser-Induced Damage in Optical Materials		CRC Press
H. Angus Macleod	2021	Thin-Film Optical Filters		CRC Press
Richard Zallen,	2008	The Physics of Amorphous Solids		Wiley
Tayyab I. Suratwala	2018	Materials Science and Technology of Optical Fabrication.		Wiley