COURSE UNIT (MODULE) DESCRIPTION

Course unit (module) title	Code
Optical System Design	

Lecturer(s)	Department(s) where the course unit (module) is delivered
Coordinator: doc. Domas Paipulas **Other(s):**	VU FF Department of quantum electronics

Study cycle	Type of the course unit (module)
First	Compulsory

Mode of delivery	Period when the course unit (module) is delivered	Language(s) of instruction
Auditorium	6 semester (spring)	Lithuanian/English

Requirements for students	
Prerequisites: General physics - Optics	**Additional requirements (if any):**

Course (module) volume in credits	Total student's workload	Contact hours	Self-study hours
5	147	67	80

Purpose of the course unit (module): programme competences to be developed
• This course introduces the principles of optical design and instrumentation. • A solid foundation of geometrical optics which includes first-order system parameters and

paraxial raytracing are given in the first part of the course. Course continues with image formation theory and influence of aberrations on the image quality. The concepts of ray and wavefront aberration are introduced and individual third-order aberration terms are analyzed. The use of ray intercept curves, wave fans and spot diagrams for aberration analyzes are discussed. The strategies for overcoming particular aberrations will be presented. Competences to apply geometrical optics principles in practice are developed.

- Students will gain skills in applying digital computational methods for system design, performance evaluation and optimization using commercial software such as OSLO or ZEMAX.

- A key elements of optical systems will be analyzed: lens, mirrors, prisms, polarizing optics elements, manufacturing of optical elements. A review of main optical devices will be given in the course including microscopes, afocal systems, optical relay systems, objectives and eyepieces, photo lenses, telephoto and machine-vision lenses. Students will gain knowledge about these devices and develop skills to use these elements in practice.

Learning outcomes of the course unit (module)	**Teaching and learning methods**	**Assessment methods**
By the end of the course students will be able to understand and analyze optical systems of various complexity, will have a practical skills to design a custom optical systems for visual or laser applications and evaluate its performance. Also students will learn to use the state-of-art digital modeling software such as OSLO and ZEMAX and apply digital computation methods for design, optimization and performance evaluation tasks. (1.3, 2.4, 3.3)	Lectures with exercise. Homework assignments. Laboratory works.	Cumulative assessment: Evaluation of lab work, Evaluation for homework; Examination.
Students will develop skills to apply theoretical knowledge to practical problem analysis and will be able to device solutions (1.3) Students will develop optical and optical engineering skills in design, evaluation and analysis of optical systems (3.3)		

Content: breakdown of the topics	**Contact hours**							**Self-study work: time and assignments**	
	Lectures	Tutorials	Seminars	Exercises	Laboratory work	Internship / work pl	**Contact hours**	**Self-study hours**	**Assignments**

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1. Geometrical and physical optics. Ray optics. Light reflection and refraction. Snell's law. Principles of image formation. Ideal optical systems. Paraxial geometrical optics. Refraction through single surface. Thin lens equation in Gaussian and Newton notations. Lateral and transverse magnifications. Optical power. Magnifying lens.	3			2			**5**	**6**	Homework assignment (from lecture material)
2. Ray propagation through many surfaces. Concepts of ray tracing. Cardinal points (principle planes, effective focal length, focal planes, nodal points, working distances). Gaussian reduction. Thick lens	3			2			**5**	**6**	Homework assignment (from lecture material)
3. Apertures in optical systems. Aperture stop and field stop, field lens. Entrance and exit pupils. Chief and marginal rays. Vignetting. First order parameters of optical system: numerical aperture, field of view, f-number. Depth of field, depth of view. Hyperfocal distance. Telecentric systems.	4		1	2			**7**	**6**	Homework assignment (from lecture material)
4. Diffraction in optical systems. Airy disk. Rayleigh criteria. Lateral and transverse aberrations, OPD (optical path difference) aberration. Spherical aberration. Coma. Astigmatism. Distortion. Petzval surface. Fighting with aberrations. Seidel coefficients. Chromatic aberration. Abbe (V) number. Achromatic, apochromatic lenses. Aplanatic surfaces. Aberration digital analysis: ray intercept curves, spot diagrams.	4			2			**6**	**6**	Homework assignment (from lecture material)
5. Microscopes. Image formation in microscope. Resolution. Magnification. Kiohler illumination. Objectives. Eyepieces. Contrast enchanting in microscopy: dark field microscopy, phase contrast, confocal microscopy, Nomarski microscope. Going beyond resolution: 4Pi and STED microscopy.	3		1	2			**6**	**6**	Homework assignment (from lecture material)
6. Afocal systems. Telescopes: catoptric, dioptric, catadioptric systems. Galileo, Kepler, Newton, Cassegrain, Ritchey–Chrétien, Schmidt, Maksutov systems. Aberration reduction in telescopes. Magnification,	3		1	2			**6**	**6**	Homework assignment (from lecture material)

resolution, field of view. Concepts of active and adaptive optics. Mega telescopes. Image relay systems.									
7. Gaussian beam in optical systems. Characterization of Gaussian beam: waist, divergence, Rayleigh length, confocal parameter. Thin lens and paraxial equations for Gaussian beam. Collimators and beam expanders. Optics for lasers.	3		1	2			**6**	**6**	Homework assignment (from lecture material)
8. Prisms and polarization control in optical systems. Total internal reflection, frustrated total internal reflection (FTIR). Rectangular prisms. Erection prisms. Tunnel diagrams. Thin prisms. Dispersion prisms. Achromatic prisms. Beam splitters. Glan and Wollaston prisms. Wave plates.	3		1	2			**6**	**6**	Homework assignment (from lecture material)
9. Optical signal detection. Diode detectors: pn, pin, avalanche detectors, CCD, CMOS sensors. Vacuum diodes, photomultipliers. Thermal detectors: bolometers, pyroelectrics, thermopiles.	3			2			**5**	**6**	Homework assignment (from lecture material)
10. Manufacturing of optical elements. Materials: glases (flint, crown), plastics. Lens grinding, coatings. Digital design of optical systems.	3		1	2			**6**	**6**	Homework assignment (from lecture material)
11. Laboratory works.					6		**6**	**10**	Each student personally will get a task to design, analyze and optimize an optical system with the digital modeling software OSLO or ZEMAX. The results of system design will be presented to other students and lecturer during the seminars
Final test	3						**3**	**10**	
Total	**32**		**6**	**20**	**6**		**67**	**80**	

Assessment strategy	Weight,%	Deadline	Assessment criteria
Laboratory works	10 %	End of semester	Main criteria – completeness of the assignment (if all objectives are fulfilled). Answering of theoretical questions during laboratory work presentation. If lab work is successfully defended student gets +1 point to exam. If lab work is unsuccessfully defended, student gets 0 points. If lab work is not defended, student gets -1 point.
Homework assignment	10 %	During all semester	Homework consist of >10 exercises that students solve independently. Solutions are evaluated. Students get +1 point if more than 75 % exercises are solved correctly, 0 points if solutions are not correct and -1 point if less than 50 % exercises are returned to lecturer before deadline.
Final test	80 %	Session	Final test (questions and exercises) from course material.

Author	Year of publication	Title	Issue of a periodical or volume of a publication	Publishing place and house or web link
Compulsary reading				
R.E. Fischer, B. Tadic-Galeb, P.R. Yoder	2008	Optical system design		McGraw-Hill Professional
W.J. Smith	2008	Modern optical engineering		McGraw-Hill Professional
Optional reading				
P. Mouroulis, J. Macdonald,	1997	Geometrical optics and optical design,		Oxford University Press
J.E. Greivenkamp	2003	Field guide to Geometrical Optics		SPIE press