University ITMO, Russia

WUT, Poland

Department of
Applied and Computer Optics
http://aco.ifmo.ru

Photonics Engineering
Division
http://zif.mchtr.pw.edu.pl

Master program "Optical Design"

Department of Applied and Computer Optics (ACO Department), St. Petersburg National Research University of Information Technologies, Mechanics and Optics (ITMO University) together with Photonics Engineering Division of Warsaw University of Technology (WUT) offers a double-degree master program "Optical Design". This program is held in English. Students are studied in the ITMO University during the first academic year and in the WUT during the second one. At the end of this program students get diplomas of both universities.

Master program topics:

- Design of high-quality optical systems for different purposes
- Optical measurements
- Computer simulation and software development for optical system design
- Optical image processing
- Design of optical devices and CALS strategy in optical engineering

Contacts

aco.ifmo@gmail.com

Program structure

Course	ECTS	Lecture	Lab./ Exercises
1 year. ITMO (Russia)			
1 semester	**30**		
CALS strategy in optical engineering	4	17	51
Optical System Design	6	17	85
Elective courses: - Optical image modeling - Design of optical devices and components	5	17	51
Elective courses: - Philosophical Anthropology and Social Philosophy - Project management	3	9	26
Research project	12	-	-
2 semester	**30**		
Composing and optical systems design	3	17	51
Elective courses: - Optical microscopes - Image Processing	3	17	51
English language	3	-	68
Elective courses: - Testing methods for optical elements and systems - Constructing and development of opto-information systems	3	17	51
Research project	6	-	-
Internship	12	-	-
2 year. WUT (Poland)			
3 semester	**30**		
Optical methods of measurements and control	5	30	20
Photonics devices and systems	5	30	15
Opto-numerical 2D/3D/4D measurements methods	4	30	10
Advanced wave propagation (with project)	4	15	15
Computer vision and angumented reality	4	15	15
Elective courses: - Biophotonics - Optics of liquid crystals - Image processing and recognition (with project) - Choice of Project at Mechatronics, Physics or EiTI Faculties WUT	6	24	6
for choice: - Polish language - English language	2	-	30
4 semester	**30**		
6-months internship in research laboratory (diploma work)	28		
Diploma seminar	2	-	30

Composing and optical systems design

	Hours						
Semester	**Workload**	**Lectures**	**Practical work**	**Lab.**	**Seminar**	**Independent studies**	**Tests**
Spring	108	17	51	0	20	20	Test

Abstract

Course “Composing and optical systems design” contains detailed consideration of main aspects of imaging optical systems design. Theory of structural and parametrical synthesis of optical systems is described. Methods for optical system starting points election are presented. Examples of modern optical systems design using modern powerful optical design software are given.

Goals and Objectives of the Course

Knowledge of

- composition of optical systems
- structural and parametric synthesis of optical systems

Theoretical Skills

- be able to select a starting point for optical system design
- be able to evaluate an optical system performance

Practical Skills

- be able to specify an optical imaging system
- be able to propose the optical system general layout

Course Prerequisites:

Knowledge in physics, geometrical and physical optics, stops and pupils, fundamentals of ray tracing, aberrations theory, ability to work with optical design software; basic knowledge of image quality criteria and skills of optical systems parameters calculation using paraxial equations.

Course Structure

Volume of the course: 3.0 ECTS credits, 108 hours

Chapter	**Types of activities**					**Total in hours**
	Lectures	**Practical work**	**Laboratory work**	**Seminar**	**Independent studies**	
Design targets and starting design	6	13	-	5	5	29
Composition of optical systems	6	20	-	8	8	42
Concept of synthesis and composing	5	18	-	7	7	37
Total:	**17**	**51**	-	**20**	**20**	**108**

Lectures

Hours	Theme
2	Acquaintance with optical design software
2	Main steps of optical design process
2	Main types and general classification of optical systems
2	Types of surfaces and elements and its aberrational properties
2	Composing of elements
2	Principles of correction and correction optical elements
2	Concept of synthesis and composing
3	Structural and parametric synthesis

Practical work

Hours	Theme
3	Technical and general classification and definition of optical system complexity
3	Acquaintance with optical design software. System analysis and image quality evaluation
4	Optical objectives modules
4	Optical surfaces types and optical elements synthesis
5	Basic optical elements and its properties
4	Correction optical elements and correction principles
4	“Fast” optical elements and its properties
4	“Wide-angular” optical elements and its properties
4	Optical elements combinations and aberrations correction
6	Structural synthesis of optical systems
5	Structural synthesis of optical systems of optical element where surfaces has well-known properties
5	Parametric synthesis of optical systems

CALS strategy in optical engineering

	Hours						
Semester	**Workload**	**Lectures**	**Practical work**	**Lab.**	**Seminar**	**Independent studies**	**Tests**
Autumn	144	17	0	51	38	38	Exam

Abstract

Course "CALS strategy in optical engineering" covers a range of issues associated with the basic principles of the organization of the optical devices design process. Basic working methods of the development of optical instruments in modern production are considered. The focus is on Continuous Acquisition and Lifecycle Support and on the documentation development process automation.

Study of the subject produces the following competencies: the ability to maintain a unified information space planning and management of the enterprise at all stages of the product life cycle; the ability to use effectively the specialized software for the automated design and CALS-tech solutions in scientific, technical, design, engineering and technological areas of the optical engineering.

Goals and Objectives of the Course

Knowledge

- basic knowledge of the information support of the product life cycle;
- the principles of organization of the design process of optical devices in the concept of information support of the product life cycle;

Theoretical Skills

- ability to perform the design documentation for the optical device;
- ability to use the modern media-aided design and engineering, and information systems to support the product lifecycle;

Practical Skills

- skills of working in a variety of modern software packages for the design documentation, product data management.

Course Prerequisites

Knowledge of higher mathematics, physics, basic geometric optics, basic engineering, computer science, the ability to develop algorithms, skills in working with a PC and software products for the computer-aided design of optical systems.

Course Structure

Volume of the course: **4**.0 ECTS credits, 144 hours

Chapter	**Types of activities**					**Total in hours**
	Lectures	**Practical work**	**Laboratory Work**	**Seminar**	**Independent studies**	
Information support of the product life cycle	8	-	21	16	16	61

Analysis of software systems to provide information support to the various stages of the product life cycle	5	-	16	10	10	42
Analysis of software systems and data formats that integrate software systems into a single information space products	4	-	14	12	12	41
Total:	**17**	**-**	**51**	**38**	**38**	**144**

Lectures

Hours	Theme
3	Life cycle of optical products. Features of the design stage of optical products
3	Information support of the product life cycle. Concept, strategy, technology and information systems for the product life cycle support.
2	Architecture and structure of the information support system of the product lifecycle
2	Research activities. Networking technologies in optical engineering. The study of actual problems of optical engineering.
2	Computer-aided design and simulation of optics. CAD/CAE/CAM.
2	Material Requirements Planning (MRP), Enterprise Resource Planning (ERP), Workflow Management (WF)
2	Product Data Management (PDM),Product Lifecycle Management (PLM).
1	Formats for the exchange of product data. Information security.

Laboratory Work

Hours	Theme
7	Life cycle of the product. Development of explanatory notes.
7	Life cycle of the product. Design of the optical system of the product.
7	Life cycle of the product. Development of the design documentation in the CAD environment.
6	Support product lifecycle in computer CAD programs (SolidWorks).
5	Support product lifecycle in computer CAD programs (TFlex).
5	Support product lifecycle in computer CAD programs (Autodesk Inventor).
14	Integration of programs into a common information space of the product.

Optical System Design

	Hours						
Semester	**Workload**	**Lectures**	**Practical work**	**Lab.**	**Seminar**	**Independent studies**	**Tests**
Autumn	216	17	-	85	57	57	Exam

Abstract

Course “Optical system design” covers the range of issues related to basic principles of designing of optical system, embracing synthesis, optimization and estimating the manufacturability. The course includes such topics as classification of aberrations that would be necessary during the analysis of the aberration properties of different optical schemes and the theory of third order aberration that may be useful for finding an initial optical scheme. The discipline also includes theoretical basis of optimization (automated correction) using special professional software, analysis and evaluation of image quality of optical systems and estimating of technological parameters for optical system fabrication.

Goals and Objectives of the Course

Knowledge of

- Theory of third order aberration
- Different criteria of image quality
- Mathematical basics of optimization

Theoretical Skills

- Knows how to create “starting” optical system for different optical devices
- Knows how to estimate the image quality of optical systems of different types
- Knows how to evaluate system sensitivity to the inaccuracy of manufacturing and to define tolerances

Practical Skills

- be able to design simple optical systems of different types, evaluate their image quality and tolerances.

Course Prerequisites

Knowledge in physics (geometric and wave optics, theory of interference and diffraction), higher mathematics (differential and integral calculus); ability to assess adequacy of modelling and designing results using knowledge of physics and mathematics, skills of working with personal computer.

Course Structure

Volume of the course: 6.0 ECTS credits, 216 hours

Chapter	**Types of activities**					**Total in hours**
	Lectures	**Practical work**	**Laboratory work**	**Seminar**	**Independent studies**	
Methods of synthesis of optical systems.	4	-	25	11	11	51

Designing of the optical systems of different types	9	-	45	23	23	100
Estimating the technological parameters of optical systems and tolerancing	4	-	15	23	23	65
Total:	**17**	**-**	**85**	**57**	**57**	**216**

Lectures

Hours	Theme
2	Classification of aberration.
2	Synthesis of optical system using theory of third order aberrations
2	Synthesis of optical system using database and the method of composition.
2	Optimization of image quality of optical system: main ideas
2	Mathematics of optimization of optical system: Newton's method, least-squares method
2	Diffraction image quality and geometrical image quality of optical systems
2	Modulation transfer function, Encircled Energy, Strehl ratio, Rayleigh criterion.
3	Manufacturability of optical system. Estimating the sensitivity to the deviation of system parameters from their design value.

Laboratory Work

Hours	Theme
2	Analysis of the third order spherical aberration
2	Analysis of the third order coma
2	Analysis of the third order astigmatism
2	Analysis of the third order image curvature
2	Analysis of the axial chromatic aberration and secondary spectrum
2	Analysis of the chromatic aberration of magnification
4	Design and analysis of doublet lens
6	Two-mirror system
10	Galilee telescope design
6	Designing the scheme for testing aspherical surfaces by conjugate focii method
6	Design and analysis of the system for IR range
8	Synthesis of the Petzval objective with Smith lens
4	Designing and researching the single lens with aspherical surface
6	Evaluating the sensitivity of the objective to the manufacturing errors.

Constructing and development of opto-information systems

	Hours						
Semester	**Workload**	**Lectures**	**Practical work**	**Lab.**	**Seminar**	**Independent studies**	**Tests**
Spring	108	17	-	51	20	20	Exam

Abstract

Course “Constructing and development of opto-information systems” describes theoretical methods of design of different optical systems. Practical recommendations for main optical systems types design are presented. During the course big amount of practical exercises of optical systems design is considered.

Goals and Objectives of the Course

Knowledge of

- constructing principles of optical systems for various implementation;
- main types of optical systems for various purposes and its specifics;

Theoretical Skills

- be able to analyse and select optical elements for optical system design;
- be able to evaluate optical system image quality.

Practical Skills

- be able to use optical design software;
- be able to create a starting design;
- to be able to optimize an optical system;

Course Prerequisites:

Knowledge in physics, geometrical and physical optics, stops and pupils, fundamentals of ray tracing, aberrations theory, ability to work with optical design software; basic knowledge of image quality criteria and skills of optical systems parameters calculation using paraxial equations.

Course Structure

Volume of the course: 6.0 ECTS credits, 216 hours

Chapter	**Types of activities**					**Total in hours**
	Lectures	**Practical work**	**Laboratory work**	**Seminar**	**Independent studies**	
Concept of optical system constructing	8	-	12	10	10	40
Construction of optical systems for various purposes	9	-	39	10	10	68
Total:	**17**	**-**	**51**	**20**	**20**	**108**

Lectures

Hours	Theme
2	General principles of constructing and developing of optical systems
2	Bottom-up and top-down approach for selecting a starting point
2	Concept of optical system constructing
2	Optimization for different examples
2	Optical systems with “Speed-up” characteristics
2	Optical systems for safety and security, covert video observation
3	UV and IR optical systems
2	Implementation of aspherical surfaces. Design camera lens for mobile phone

Laboratory Work

Hours	Theme
4	Starting the optical scheme
4	Synthesis of starting point for fish-eye lens with aplanatic and concentric surfaces
4	Optimization for different examples
4	Design of eyepiece
4	Optical module as a starting optical system
4	Design camera lens for mobile phone
4	Mirror and catadioptric systems design
3	Fresnel lenses
4	Zoom lenses
4	Design of pinhole lens
4	Design a symmetrical system
4	Design of relay lens
4	Telephotolens

Testing methods for optical elements and systems

	Hours						
Semester	**Workload**	**Lectures**	**Practical work**	**Lab.**	**Seminar**	**Independent studies**	**Tests**
Autumn	108	17	-	51	20	20	Exam

Abstract

Course “Testing methods for optical elements and systems” covers the area connected with the estimation of optical elements and optical systems quality during manufacturing. Basic methods for testing of optical surfaces (flat, spherical and aspherical) and inhomogeneity of refraction index are discussed, focusing on interferometric testing methods. The scheme of interferometers and the layout for testing different objects are considered. Attention are also paid to the mathematical basis of wavefront description and interferogramm processing. Methods and setups for testing of optical system quality are also dealt with. Laboratory practicum gives practice of adjustment optical measurement devices, practical work with optical elements and also measurement results processing.

The course gives understanding of theoretical basic of interferometric test methods, Hartmann method and other optical characteristics control methods and gives experience of working using real optical instruments and equipment, develops practical skills of testing optical element and systems.

Goals and Objectives of the Course

Knowledge of

- Principles of testing of quality of optical elements and systems
- Special features of testing methods for different optical systems
- Range of application of different testing methods
- Mathematical apparatus used for description of wavefront and for measurement results processing
- Criteria of image quality for different optical elements and systems

Theoretical Skills

- be able to estimate quality of optical elements and system
- be able to apply different quality criteria

Practical Skills

- be able to receive interferogramm for optical surface,
- be able to process and analyse interferogram using special software
- to be able to set up and adjust the scheme for interferometric control of optical elements.
- To be able to deal with special software for generating and processing of interferogram
- beabletoprocessandinterprettheresultsof testing of the optical elements and systems

Course Prerequisites:

Knowledge in optics basics (geometric and wave optics), physics (theory of interference and diffraction); knowledge of mathematics (differential and integral calculus, basics of complex variable theory, the theory of series); knowledge of simple optical devices (a microscope, a telescope system, an objective); ability to assess adequacy of measurement results using

knowledge of physics, optics and mathematics; skills of working with personal computer and software for mathematical calculation.

Course Structure

Volume of the course: 3.0 ECTS credits, 108 hours

Chapter	Types of activities					Total in hours
	Lectures	Practical work	Laboratory work	Seminar	Independent studies	
Theoretical basic of optical testing methods	4	-	8	5	5	22
Interferometric testing methods and schemes of interferometers	6	-	18	4	4	32
Schemes and methods for testing optical elements and systems	7	-	25	11	11	54
Total:	**17**	**-**	**51**	**20**	**20**	**108**

Lectures

Hours	Theme
3	Basic principles of testing methods. Objects for testing.
3	Characteristics and criteria of image quality
2	Interferometric testing methods. Schemes of interferometers.
2	Registration and processing of interferogram. Phase-shifting interferometric methods.
2	Flat wavefront testing. Testing of inhomogeneity of refraction index
3	Testing of spherical and aspherical surfaces. Testing of the objectives and telescopic systems .
2	Measurement of encircled energy and modulation transfer function.

Laboratory Work

Hours	Theme
4	Wavefront reconstruction for given interferogramm
6	Testing flat surfaces on Fizeau interferometer
5	Receiving interferogram and its processing using Fourier transform
6	Testing flat surfaces by phase-shifting method
8	Testing the refractive index inhomogeneity using Fizeau interferometer
8	Testing the image quality of the objective on Fizeau interferometer
6	Processing the results of Hartman control method
8	Measuring the modulation transfer function using rectangular cycles test-object

Design of optical devices and components

	Hours						
Semester	**Workload**	**Lectures**	**Practical work**	**Lab.**	**Seminar**	**Independent studies**	**Tests**
Autumn	180	17	17	34	56	56	Exam

Abstract

Discipline covers a range of issues related to the principles of design of optical devices. Basic working methods of the development of optical instruments in the modern production are considered. The focus is on the design and development of device units. The effective work in CAD systems is also considered.

Study of the subject produces the following **competencies:** ability to carry out effectively the implementation of a circuit and instrumentation solutions for the selected task of optical engineering; ability to analyze the design and construction of an optical device, synthesize new versions based on knowledge of the physical principles of operation of systems and components, including design and technology requirements for the device, individual blocks and components; ability to make out the results of the project activities in accordance with the requirements of the standards

Goals and Objectives of the Course

knowledge of: the design development features of the optical device, depending on its purpose and the conditions of the device operation;

abilities to: work out the design components of optical devices, to develop a software and other support for the automation of the design process;

skills in: the area of the modern production of the design documentation and automation design documentation.

Course Prerequisites:

The necessary conditions for studying the discipline are: knowledge of higher mathematics, physics, basic geometric optics, basic engineering, computer science, the ability to develop algorithms, skills to work with a PC and products for computer-aided design of optical systems.

Course Structure

Volume of the course: 5.0 ECTS credits, 180 hours

Chapter	**Types of activities**					**Total in hours**
	Lectures	**Practical work**	**Laboratory work**	**Seminar**	**Independent studies**	
Workflow optical devices	2	4	8	13	13	40
Basic requirements for the optical and opto-electronic devices	6	4	8	13	13	44

The arrangement of optoelectronic devices	7	4	8	13	13	45
Application of CAD systems in an optical instrument making	2	5	10	17	17	51
Total:	**17**	**17**	**34**	**56**	**56**	**180**

Lectures

Hours	Theme
2	Workflow optical devices
2	Basic requirements for the optical and opto-electronic devices
2	The calculation and selection of basic parameters of optical devices
2	The arrangement of optoelectronic devices
4	Features of the design of optical and opto-mechanical components of optoelectronic devices
3	Features of the calculation and selection of the optical devices
2	Application of CAD systems in an optical instrument making

Laboratory Work

Hours	Theme
4	Evaluation of ergonomic and aesthetical indicators of quality optical device
4	Development of drawings for optical components and options for mounting it
5	Development of routing device assembly site
4	Development of the construction unit of the radiation source with the LED technology example
5	Development of working sketches of the optical device elements

Practical Work

Hours	Theme
4	Elaborate TOR
4	Development of technical proposals
5	Quality rating element optical device for accuracy and conjugation. Calculation of tolerances and fits on the dimensions of the optical device elements
4	The choice of materials in order to take into account the weight and metal

Optical image modelling

	Hours						
Semester	**Workload**	**Lectures**	**Practical work**	**Lab.**	**Seminar**	**Independent studies**	**Tests**
Autumn	180	17	17	34	56	56	Exam

Abstract

Theoretical part of the course includes basic optical imaging theory: electromagnetic waves, Maxwell's equation, diffraction and image formation, partial coherence, aberration and image quality, etc. Practical part of the course includes optical image modeling in C++.

Goals and objectives of the course

Knowledge of:

- basics of image formation
- diffraction models
- image quality assessment
- mathematical description and algorithms of image forming at coherent, incoherent and partial coherent illumination

Practical Skills:

- be able to develop C++ module of image formation, and choose appropriate numerical methods for modeling

Course Prerequisites

Knowledge in: physics (optics), mathematical analyses, ability to work with mathematical software, basic knowledge of C/C++, basic knowledge of numerical methods (FFT).

Course Structure

Volume of the course: 5.0 ECTS credits, 180 hours

Chapter	**Types of activities**					**Total in hours**
	Lectures	**Practical work**	**Laboratory work**	**Seminar**	**Independent studies**	
Basics of electromagnetic theory.	4	2	--	10	10	26
Imaging theory. Diffraction.	7	4	24	23	23	74
Image formation via signal transformation	6	11	10	23	236	80
Total:	**17**	**17**	**34**	**56**	**56**	**180**

Lectures

Hours	Theme
4	Basics of electromagnetic theory. Maxwell’s equations and the wave equation.
3	Imagingtheory. Diffraction.
4	Mathematical description and algorithms of image forming at coherent, incoherent and partial coherent illumination.
3	Image quality parameters. Aberrations. PSF. MTF.
3	Image formation via signal transformation

Practical work

Hours	Theme
2	Discussions and tests for section "Basics of electromagnetic theory"
4	Discussions and tests for section "Imaging theory. Diffraction."
11	Discussions and tests for section "Image formation via signal transformation "

Laboratory Work

Hours	Theme
14	The simulation of the image formation in coherent, incoherent and partially coherent light for an ideal optical system
10	The study of the effect of different types of aberrations on the PSF, OTF and the image with incoherent illumination
10	Modeling the influence of various factors on formation of the optical image

Image processing

	Hours						
Semester	**Workload**	**Lectures**	**Practical work**	**Lab.**	**Seminar**	**Independent studies**	**Tests**
spring	108	17	-	51	20	20	Exam

Abstract

Course “Image processing” covers wide range of issues, related to main methods of image processing for visual improvement. The course includes the study of main color models and their mutual conversions, methods of element wise image processing, including methods of preparation. The main emphasis of the course is on methods of image improvement and recovery using different kinds of filtering.

Goals and Objectives of the Course

Knowledge of

- modern principles of computer coding of images, including methods of color-coding;
- basic computer image processing algorithms and their practical importance;
- theory of digital signal processing and methods of image processing.

Theoretical Skills

- be able to assess the need for methods of image processing;
- be able to choose the most productive method for image processing.

Practical Skills

- be able to use methods and means of computer processing of images;
- be able to implement mathematical models of image processing in the form of software modules.

Course Prerequisites:

Knowledge in: physics, mathematical analyses, theory of geometrical and physical optics; ability to work with mathematical apparatus and mathematical software; basic knowledge of C/C++ and basic skills in GUI programming (Qt or MFC).

Course Structure

Volume of the course: 3.0 ECTS credits, 108 hours

Chapter	Types of activities					Total in hours
	Lectures	Practical work	Laboratory work	Seminar	Independent studies	
Basics of registration, modeling and digital processing optical image	8	-	24	6	6	52
Methods and algorithms for optical image processing	9	-	27	14	14	56
Total:	**17**	**-**	**51**	**20**	**20**	**108**

Lectures

Hours	Theme
2	Image formation. Registration and coding optical image. Sampling and quantization of the image.
2	Basics of digital processing of optical signals. Mechanisms of image compression.
2	Color spaces and color coding standards.
2	Improving the visual quality of the image. Element wise image processing.
2	Geometric image transformation.
2	Logical image transformation. Arithmetic image transformations.
2	Filtering image. Selection of the optimal method of filtering image.
3	Image restoration. Image models and their distortions

Laboratory Work

Hours	Theme
4	Registration and image inputs to the computer. Implementation of algorithms for reading and writing images using raster image formats.
7	Implementation and study methods of images preparation.
8	Implementation and study of methods of geometrical transformations images.
14	Implementation and study of methods of logical and arithmetic transformations images.
8	Implementation and study of methods of image filtering.
10	Implementation and study of methods of image distortions and methods of their compensation