Course “Optical image modelling”

Field of study: Optical Design
Course level: Master
Specialization: 200400.68. Optical Design

	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**	
1.Basics of electromagnetic theory.	4	2	--	10	10	26
2.Imaging theory. Diffraction.	7	4	24	23	23	74
3.Image formation via signal transformation	6	11	10	23	236	80
Total:	**17**	**17**	**34**	**56**	**56**	**180**

1. Basics of electromagnetic theory.
   1.1. The modeling of light propagation
   1.2. The superposition of light waves with regard to their coherence
   1.3. The simulation of diffraction phenomena
2. The diffraction theory of image formation
   2.1. Modeling of the propagation of light through an optical system
   2.2. Models of image formation by the optical system
   2.3. The diffractive field propagation in the object space
   2.4. Geometric field propagation through the optical system
   2.5. The diffractive field propagation in the image space
   2.6. The algorithm for modeling the propagation of the field through the optical system
   2.7. The formation of images of self-luminous objects
   2.8. The description of properties of illuminated objects
   2.9. Determination of the coherence properties of illumination
   2.10. Formation of images of objects in transmitted light
   2.11. Algorithms for modeling of formation of the optical image
3. Image formation via signal transformation
   3.1. The transformation of signals by optical systems
   3.2. Quality characteristics of optical systems
   3.3. The frequency description of signal conversion
   3.4. The optical transfer function and it's properties
   3.5. The formation of images by a cascade of converters

Lectures

Hours	Theme
4	Basics of electromagnetic theory. Maxwell's equations and the wave equation.
3	Imaging theory. 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

Independent studies

- Preparing for laboratory works
- Writing reports
- Home work

Assessment Methods

- Test;
- Laboratory work;
- Home tasks
- Personal skills of a student are estimated;
- Exam

Lab works description

Lab 1. The simulation of the image formation in coherent, incoherent and partially coherent light for an ideal optical system

The goal is to acquire the practical skills of modeling the formation of the optical image by an ideal optical system in a coherent, incoherent and partially coherent light.

The sequence of key actions: the creation of the structure of classes needed for modeling (sampling, object, image, the optical system). Generation of the object in the form of a periodic lattice. The implementation of algorithms to simulate the formation of an ideal optical system's optical image in coherent, incoherent and partially coherent light. The study of numerical modeling parameters and their influence on the resulting image. The analysis of the resulting image, the PSF and the CTF.

Lab 2. The study of the effect of different types of aberrations on the PSF, OTF and the image with incoherent illumination

The goal is to acquire the practical skills of assessing the quality of the image and of modeling the effect of aberrations on the quality of the optical image.

The sequence of key actions: the creation of a structure of classes needed for modeling (sampling, object, image, the optical system, Zernike polynomials). Adding aberrations into the algorithm of modeling the formation of ideal optical system (that was implemented under lab №1) depending on the individual task. The study of the influence of given aberrations on the resulting image. Analysis of the resulting image, the PSF and CTF. Creation of a report with examples of given aberrations and the resulting image, PSF, CTF, and calculated on their basis characteristics of quality.

Lab 3. Modeling the influence of various factors on formation of the optical image

The goal is to acquire the practical skills of modeling various factors that influence the formation of the optical image.

The sequence of key actions: the creation of a structure of classes needed for modeling depending on the individual variant of the task. Adding various factors that influence the image quality(aberrations, uneven transmission over the pupil, the pupil of a complex shape, the light source of a complex shape, a phase object etc.) into the algorithm of modeling the formation of an ideal optical system (that was implemented under lab №1). The sstudy of the influence of selected factors on the resulting image. Analysis of the resulting image, the PSF and CTF. Creation of a report with examples of set parameters, the resulting image and the characteristics showing the influence of the given factor.