Fachhochschule Münster University of Applied Sciences

Modulhandbuch / Module Guide

Master of Science

Photonics

Fachhochschule Münster
Fachbereich Physikalische Technik
Stegerwaldstraße 39
48565 Steinfurt

Version 2011.2

Modulliste – List of Modules

Pflichtmodule – Compulsory Modules

TL	Module	Term
E	Laser Materials Processing	W
E	Laser Measurement Technology	S
E	Laser Physics	W
E	Optical Measurement Technology	W
E	Optical Systems Design	W
	Semiconductor Technology and MOEMS Design Using FEM	
E	- Semiconductor Technology	W
E	- MOEMS Design Using FEM	S
E	Solid State Laser Engineering	W
E	Theoretical Optics	W
	Wave and Quantum Optics	
E	- Wave Optics	S
E	- Quantum Optics	W

Wahlpflichtmodule – Compulsory Elective Modules

Four modules have to be chosen from the following list

TL	Module	Term
E	Incoherent Light Sources	S
D	Industrielle Bildverarbeitung	W
D	Mikroskopische Verfahren und Oberflächenanalytik	S
E	Nanotechnology	W
E	Optical Communications	W
D	Optische Funktionsmaterialien	S
D	Photovoltaik	S
D / E	Seminararbeit / Seminar Paper	W

TL	Unterrichtssprache / Teaching Language
E	Englisch / English
D	Deutsch / German
W	Wintersemester / Winter term
S	Sommersemester / Summer term

Studienverlaufsplan / Curriculum

	Language	1. Semester (winter)					2. Semester (summer)					3. Semester (winter)				
	(E = English)	SWS				*CP*	SWS				*CP*	SWS				*CP*
	(D= Deutsch)	V	SU	Ü	P		V	SU	Ü	P		V	SA	Ü	P	
Foundations in Mathematics, Natural Science, and Technology																
Theoretical Optics	E	3		2		*7*										
Laser Physics	E	2		1	2	*7*										
Semiconductor Technology *	E	2		1		*4*										
Wave and Quantum Optics: Wave Optics **	E						2		1	2	*7*					
Wave and Quantum Optics: Quantum Optics **	E											2		1		*4*
Systems:																
Optical Systems Design	E	2			2	6										
MOEMS Design Using FEM *	E						2			2	5					
Solid State Laser Engineering	E											2		1	2	7
Applications:																
Laser Measurement Technology	E						2			2	6					
Laser Materials Processing	E											2			2	6
Optical Measurement Technology	E											2		1	2	7
Compulsory Elective Course (four courses from the following catalog):																
Nanotechnology	E	2	1			6										
Optical Communications	E	2		1	1	6										
Incoherent Light Sources	E						3	1	1		6					
Seminar Paper / Studienarbeit	E / D												4			6
Industrielle Bildverarbeitung	D		2		2	6										
Mikroskopische Verfahren u. Oberflächenanalytik	D							3		2	6					
Photovoltaik	D						2		1	1	6					
Optische Funktionsmaterialien	D	2		1	2	6										

SWS = Semester Wochenstunden / semester periods per week
V = Vorlesung / Lecture
SU = Seminaristischer Unterricht / Seminar
SA = Studienarbeit / Seminar paper
Ü = Übung / Tutorial
P = Praktikum / Laboratory course
D = Deutsch / German
E = Englisch / English

* Semiconductor Technology and MOEMS Design Using FEA together constitute one module.
** Wave Optics and Quantum Optics together constitute one module

Modulverzeichnis / Table of Modules

1 Incoherent Light Sources

<table>
<tr><td colspan="2">Module title</td><td colspan="4">Incoherent Light Sources</td></tr>
<tr><td colspan="2">Term</td><td colspan="2">2nd semester</td><td colspan="2">summer</td></tr>
<tr><td colspan="2">Duration</td><td colspan="4">1 semester</td></tr>
<tr><td colspan="2">Responsibility</td><td colspan="4">Prof. Dr. Thomas Jüstel</td></tr>
<tr><td colspan="2">Lecturer</td><td colspan="4">Prof. Dr. Thomas Jüstel</td></tr>
<tr><td colspan="2">Language</td><td colspan="4">English</td></tr>
<tr><td colspan="2">Programs in which the module is used</td><td colspan="2">Master of Science in Chemical Engineering
Master of Science in Photonics</td><td colspan="2">optional module
optional module</td></tr>
<tr><td rowspan="9">W O R K L O A D</td><td rowspan="4">Contact hours</td><td>Courses</td><td>credit hours</td><td>semester load</td><td>contact time</td></tr>
<tr><td>Lectures</td><td>3</td><td>45 h</td><td rowspan="3">75 h</td></tr>
<tr><td>Exercises</td><td>1</td><td>15 h</td></tr>
<tr><td>Seminar</td><td>1</td><td>15 h</td></tr>
<tr><td rowspan="4">Self study</td><td colspan="2">Form</td><td>semester load</td><td>self study</td></tr>
<tr><td colspan="2">Preparation and follow-up of lectures including exercises</td><td>45 h</td><td rowspan="3">105 h</td></tr>
<tr><td colspan="2">Preparation of presentation</td><td>30 h</td></tr>
<tr><td colspan="2">Preparation of exam</td><td>30 h</td></tr>
<tr><td colspan="4">Total work load</td><td>180 h</td></tr>
<tr><td colspan="2">Credit points</td><td colspan="4">6</td></tr>
<tr><td colspan="2">Learning objectives</td><td colspan="4">Students get to know the physical concepts of lighting as well as their technical application in light sources and emissive displays. They will be able to select suitable light sources, optical materials and lighting concepts according to the specific requirements of a variety of technical application area.</td></tr>
<tr><td colspan="2">Content</td><td colspan="4">- History of (electrical) light generation
- Lighting terms and quantities
- Thermal radiation sources
- Low pressure discharge lamps
- High pressure discharge lamps
- Plasma display panels (gas discharge displays)
- Inorganic and organic light emitting diodes (LEDs)
- Luminescent materials for fluorescent lamps
- EUV-, VUV- and UV-A/B/C light sources
- Future employment of light in technology and every day life</td></tr>
<tr><td colspan="2">Requirements for participation</td><td colspan="4">Fundamental physics (geometric optics, basics of quantum mechanics), general chemistry</td></tr>
<tr><td colspan="2">Requirements for allocation of credits</td><td colspan="4">Passing of exam</td></tr>
<tr><td colspan="2">Exam</td><td colspan="4">Written (180 min) or oral (45 min) exam</td></tr>
<tr><td colspan="2">Requirements to attend the exam</td><td colspan="4">Oral presentation during seminar</td></tr>
</table>

2 Industrielle Bildverarbeitung

<table>
<tr><td colspan="2">Module title</td><td colspan="4">Industrielle Bildverarbeitung</td></tr>
<tr><td colspan="2">Term</td><td colspan="2">1. Semester</td><td colspan="2">Winter</td></tr>
<tr><td colspan="2">Duration</td><td colspan="4">1 Semester</td></tr>
<tr><td colspan="2">Responsibility</td><td colspan="4">Prof. Dr. Thomas Rose</td></tr>
<tr><td colspan="2">Lecturer</td><td colspan="4">Prof. Dr. Thomas Rose</td></tr>
<tr><td colspan="2">Language</td><td colspan="4">Deutsch</td></tr>
<tr><td colspan="2">Programs in which the module is used</td><td colspan="3">Master of Science in Photonics</td><td>optional module</td></tr>
<tr><td rowspan="6">W O R K

L O A D</td><td rowspan="3">Contact hours</td><td>Courses</td><td>credit hours</td><td>semester load</td><td>contact time</td></tr>
<tr><td>Seminaristischer Unterricht</td><td>2</td><td>30 h</td><td rowspan="2">60 h</td></tr>
<tr><td>Praktikum</td><td>2</td><td>30 h</td></tr>
<tr><td rowspan="2">Self study</td><td colspan="2">Form</td><td>semester load</td><td>self study</td></tr>
<tr><td colspan="2">Selbststudium</td><td>120 h</td><td>120 h</td></tr>
<tr><td colspan="4">Total work load</td><td>180 h</td></tr>
<tr><td colspan="2">Credit points</td><td colspan="4">6</td></tr>
<tr><td colspan="2">Learning objectives</td><td colspan="4">Die Studierenden sollen die Grundlagen der industriellen Bildverarbeitung kennenlernen und in die Lage versetzt werden, für Fragestellungen der industriellen Prüftechnik geeignete Bildverarbeitungssysteme zu entwerfen, aufzubauen und anzuwenden.</td></tr>
<tr><td colspan="2">Content</td><td colspan="4">Seminaristischer Unterricht
- Einführung: industrielle Anwendungen von Bildverarbeitung
- zweidimensionale Bildverarbeitung: typischer Aufbau eines Systems, Optik für Beleuchtung und Kamera, Bildvorverareitung, Bildbearbeitung, Merkmalsextraktion, Klassifizierung
- dreidimensionale Bildverarbeitung: typische Aufbauten und Verfahren

Praktikum
- Versuche zu den Grundlagen und Anwendungen der industriellen Bildverarbeitung</td></tr>
<tr><td colspan="2">Requirements for participation</td><td colspan="4">Die Veranstaltungen bauen auf den Veranstaltungen Mathematik I und II, Physik I und II, Elektrotechnik, Analog- und Digitaltechnik und Sensortechnik des Bachelor-Studiengangs Physikalische Technik auf.</td></tr>
<tr><td colspan="2">Requirements for allocation of credits</td><td colspan="4">Anerkennung der Ausarbeitung zum Praktikum
Bestehen der Prüfung</td></tr>
<tr><td colspan="2">Exam</td><td colspan="4">Klausur oder mündliche Prüfung oder Belegarbeit oder Präsentation</td></tr>
<tr><td colspan="2">Requirements to attend the exam</td><td colspan="4">Anerkennung der Ausarbeitung zum Praktikum</td></tr>
</table>

3 Laser Materials Processing

Module title		Laser Materials Processing			
Term		3rd semester		winter	
Duration		1 semester			
Responsibility		Prof. Dr. Klaus Dickmann			
Lecturer		Prof. Dr. Klaus Dickmann			
Language		English / German in agreement with the students			
Programs in which the module is used		Master of Science in Photonics		compulsory module	
WORK LOAD	Tuition Mode / Contact hours	Courses	credit hours	semester load	contact time
		Lectures	2	30 h	
		Laboratory course	2	30 h	60 h
	Self study	Form		semester load	self study
		Self study		60 h	
		Preparation		30 h	
		Literature study		26 h	116 h
				Total work load	176 h
Credit points		6			
Learning objectives		Based on the content of this lecture the students shall be able to develop new methods in laser material processing. Furthermore they will gain experience in understanding the interaction process of laser radiation with matter (e.g. for subsequent PhD)			
Content		Introduction of laser sources for material processing (Nd:YAG, Excimer, CO2, high power diode lasers, disk and fibre lasers), definition of beam parameters (quality, modes, power, polarisation), beam delivery (e.g. fibre optics), beam forming, focussing for micro machining, beam forming for diode lasers, interaction of radiation with matter, laser machines, processing methods (e.g. cutting, welding, drilling, surface treatment), presentation of current studies from the lab. For the laboratory course various modern high power laser machines are employed for experiments; one issue is also process monitoring.			
Requirements for participation		This lecture is based on knowledge of previous lectures: laser fundamentals, laser physics, quantum physics, mathematics, technical optics I/II			
Requirements for allocation of credits		Laboratory course needs participation in preceding laser safety course			
Exam		Oral or written examination, depending on the attendance			
Requirements to attend the exam		Successful completion of laboratory course			

4 Laser Measurement Technology

Module title		Laser Measurement Technology			
Term		2nd semester		summer	
Duration		1 semester			
Responsibility		Prof. Dr. Klaus Dickmann			
Lecturer		Prof. Dr. Klaus Dickmann			
Language		English/German in agreement with the students			
Programs in which the module is used		Master of Science in Photonics		compulsory module	
WORK LOAD	Contact hours	Courses	credit hours	semester load	contact time
		Lectures	2	30 h	
		Laboratory courses	2	30 h	60 h
	Self study	Form		semester load	self study
		Self study		60 h	
		Preparation		30 h	
		Literature study		26 h	116 h
				Total work load	176 h
Credit points		6			
Learning objectives		Based on the content of this lecture the students shall be able to apply lasers for scientific and technical applications in the field of measurement technology. Furthermore they will gain experience in order to work out self-contained solutions (e.g. PhD)			
Content		White light interferometry, laser interferometer (incl. angle, planarity), other interferometers, holographic interferometry (incl. phase shift analysis), speckle, doppler anemometer, laser gyro, Lambda meter, spectroscopy (fluorescence, emission, raman, LIDAR, LIPS), confocal laser scanning microscope, hatmann-shack-principle, laser beam diagnostic			
Requirements for participation		This lecture is based on knowledge of previous lectures: laser fundamentals, laser physics, quantum physics, mathematics, technical optics I/II			
Requirements for allocation of credits		Laboratory course needs participation in preceding laser safety course			
Exam		Oral or written examination, depending on the attendance			
Requirements to attend the exam		Successful completion of laboratory course			

5 Laser Physics

Module title		Laser Physics			
Term		1st semester		winter	
Duration		1 semester			
Responsibility		Prof. Dr. Klaus Dickmann			
Lecturer		Prof. Dr. Klaus Dickmann			
Language		English / German in agreement with the students			
Programs in which the module is used		Master of Science in Photonics		compulsory module	
W O R K L O A D	Contact hours	Courses	credit hours	semester load	contact time
		Lectures	2	30 h	
		Tutorial	1	15 h	
		Laboratory courses	2	30 h	75 h
	Self study	Form		semester load	self study
		Self study		60 h	
		Preparation		40 h	
		Literature Study		30 h	130 h
				Total work load	205 h
Credit points		7			
Learning objectives		Experience in theory of laser fundamentals in order to prepare the students for the following lectures: Solid State Laser Engineering, Laser Measurement Technology, Optical Communications, Laser Materials Processing. Furthermore it is the objective of this lecture to impart knowledge in order to enable scientific research projects for the students.			
Content		Laser fundamentals (amplification, resonator, excitation), rate equations (static and dynamic solutions), Gauß-beam propagation (inside and outside resonators), longitudinal and transversal modes, influences on modes, linewidth and possibilities of influence, frequency multiplying in non-linear crystals, further non-linear effects (e.g. OPO), generation of short pulses (e.g. Q-switch, mode-locking), specific laser systems for practice, main focus: exitation with diode lasers, x-ray-lasers, free electron lasers. In the laboratory course the master students will strengthen their understanding of laser phyiscs. Therefore several modular experimental laser set-ups are available.			
Requirements for participation		This lecture is based on knowledge of previous lectures: laser fundamentals, quantum physics, mathematics, technical optics I/II			
Requirements for allocation of credits		Laboratory course needs participation in preceding laser safety course			
Exam		Oral or written examination, depending on the attendance			
Requirements to attend the exam		Successful completion of laboratory course			

6 Master Thesis

<table>
<tr><td colspan="2">Module title</td><td colspan="4">Master Thesis</td></tr>
<tr><td colspan="2">Term</td><td colspan="2">4th semester</td><td colspan="2">summer</td></tr>
<tr><td colspan="2">Duration</td><td colspan="4">1 semester</td></tr>
<tr><td colspan="2">Responsibility</td><td colspan="4">A professor of the department of Applied Physics</td></tr>
<tr><td colspan="2">Lecturer</td><td colspan="4">n/a</td></tr>
<tr><td colspan="2">Language</td><td colspan="4">English or German</td></tr>
<tr><td colspan="2">Programs in which the module is used</td><td colspan="2">Master of Science in Photonics</td><td colspan="2">compulsory module</td></tr>
<tr><td rowspan="10">W O R K L O A D</td><td rowspan="4">Contact hours</td><td>Courses</td><td>credit hours</td><td>semester load</td><td>contact time</td></tr>
<tr><td>Lectures</td><td>0</td><td>0</td><td rowspan="3">0</td></tr>
<tr><td>Tutorial</td><td>0</td><td>0</td></tr>
<tr><td>Laboratory courses</td><td>0</td><td>0</td></tr>
<tr><td rowspan="4">Self study</td><td colspan="2">Form</td><td>semester load</td><td></td></tr>
<tr><td colspan="2">Self study</td><td>650 h</td><td rowspan="3">1 h</td></tr>
<tr><td colspan="2">Preparation</td><td></td></tr>
<tr><td colspan="2">Literature Study</td><td>100 h</td></tr>
<tr><td colspan="4">Total work load</td><td>750 h</td></tr>
<tr><td colspan="5"></td></tr>
<tr><td colspan="2">Credit points</td><td colspan="4">25</td></tr>
<tr><td colspan="2">Learning objectives</td><td colspan="4">The students shall learn to pursue a self-contained project within a specified time. This requires specific knowledge in photonics as well as interdisciplinary knowledge and a broad overview of related scientific fields. At the end, the students will have gained project management skills as well as reporting and presentation skills.</td></tr>
<tr><td colspan="2">Content</td><td colspan="4">The project shall be an application-oriented research topic in photonics.</td></tr>
<tr><td colspan="2">Requirements for participation</td><td colspan="4">See “Besondere Bestimmungen der Prüfungsordnung für den Masterstudiengang Photonics”.</td></tr>
<tr><td colspan="2">Requirements for allocation of credits</td><td colspan="4">Timely submission of the written thesis.</td></tr>
<tr><td colspan="2">Exam</td><td colspan="4">n/a</td></tr>
<tr><td colspan="2">Requirements to attend the exam</td><td colspan="4">n/a</td></tr>
</table>

7 Mikroskopische Verfahren und Oberflächenanalytik

Module title		Mikroskopische Verfahren und Oberflächenanalytik			
Term		2. Semester	Sommer		
Duration		1 Semester			
Responsibility		Prof. Dr. B. Lödding			
Lecturer		Prof. Dr. B. Lödding			
Language		Deutsch			
Programs in which the module is used		Master of Science in Photonics		optional module	
WORK LOAD	Contact hours	Courses	credit hours	semester load	contact time
		Seminaristischer Unterricht	3	45 h	75 h
		Praktikum	2	30 h	
	Self study	Form		semester load	self study
		Selbststudium		100 h	100 h
				Total work load	175 h
Credit points		6			
Learning objectives		Die Studierenden sollen einen Überblick über die Verfahren der Mikroskopie, Elektronenmikroskopie und der Oberflächenanalytik besitzen und vertiefte praktische Kenntnisse für die eigenständige Durchführung raster-elektronenmikroskopischer Untersuchungen erworben haben.			
Content		- Lichtmikroskopie (Grundlagen und moderne Verfahren) - Elektronenmikroskopie (REM und TEM) - Röntgenmikroanalyse (EDX, WDX) - Rastersondenmikroskopie (AFM, STM) - Spezielle Verfahren der Oberflächenanalytik (SIMS, XPS, AES)			
Requirements for participation		keine			
Requirements for allocation of credits		Anerkennung der Ausarbeitungen zum Praktikum Bestehen der Prüfung			
Exam		Klausur oder mündliche Prüfung			
Requirements to attend the exam		Die Zulassung zur Prüfung setzt eine erfolgreiche Durchführung des Praktikums (Durchführung einer eigenständigen REM- Untersuchung und Verfassung eines Analyseberichtes) voraus			

8 Nanotechnology

Module title		Nanotechnolgy			
Term		1st semester	winter		
Duration		1 semester			
Responsibility		Prof. Dr. M. Bredol			
Lecturer		Prof. Dr. M. Bredol Prof. Dr. U. Kynast Prof. Dr. T. Jüstel			
Language		English			
Programs in which the module is used		Master of Science in Chemical Engineering Master or Science in Photonics		optional module optional module	
WORK LOAD	Contact hours	Courses	credit hours	semester load	contact time
		Lectures	2	30 h	45 h
		Seminar	1	15 h	
	Self study	Form		semester load	self study
		Self study		135 h	135 h
				Total work load	180 h
Credit points		6			
Learning objectives		Students are familiar with concepts and technologies exhibiting and using size-dependent properties. In most cases, the associated spatial dimensions will be on the nm-scale. They have a good knowledge about chemistry-driven control of phenomena and applications.			
Content		Introduction in nanotechnology: Definition, scientific and industrial fields of nanotechnology, disciplines involved, state of theoretical background Nanoparticles: Metal nanoparticles: preparation, immobilization, application (e.g. catalysts, sensors, electronics). Semiconduction and functional ceramic nanoparticles: preparation, surface chemistry, colloid chemistry, doping, applications (e.g. biomarkers, luminescent materials, sensors). Hybrid structures: Polymers and suprachemical entities with organic and inorganic building blocks, structural templates, zeolites and mesoporous systems as hosts, sol-gel-chemistry with organic modified precursors, immobilization of biological entities Self assembly: Principles of self assembly in one, two, three and fractal dimensions (e.g. dendrimers, Langmuir-Blodgett layers, membrandes, colloidal crystals, lyotropica mesophases). Applications in optical and magnetic systems (e.g. photonica cystals, diluted ferromagnets)			

	Organic nanostructures and nanoparticles: Thin layer systems on organic basis, e.g. OLED's based on polymers or small molecules, ion conducting polymers and structures (e.g. fuell cell membranes, battery mebranes). Coatings with nanostructure: Protective coatings with nanofillers, optical coatings, ptterning methods (e.g. by photolithographical methods), direct writing ob patterned systems (2D and 3D-approaches).
Requirements for participation	Topics of Inorganic and Physical Chemistry from a B.Sc.-programme in chemistry, chemistry engineering or similar course programmes
Requirements for allocation of credits	Passing the examination
Exam	Exam (120 minutes) oral exam.
Requirements to attend the exam	

9 Optical Communications

<table>
<tr><td colspan="2">Module title</td><td colspan="4">Optical Communications</td></tr>
<tr><td colspan="2">Term</td><td colspan="2">1st semester</td><td colspan="2">winter</td></tr>
<tr><td colspan="2">Duration</td><td colspan="4">1 semester</td></tr>
<tr><td colspan="2">Responsibility</td><td colspan="4">Prof. Dr.-Ing. Konrad Mertens</td></tr>
<tr><td colspan="2">Lecturer</td><td colspan="4">Prof. Dr.-Ing. Konrad Mertens</td></tr>
<tr><td colspan="2">Language</td><td colspan="4">English</td></tr>
<tr><td colspan="2">Programs in which the module is used</td><td colspan="2">Master of Science in Informationstechnik (FB 2)
Master of Science in Photonics</td><td colspan="2">optional module
optional module</td></tr>
<tr><td rowspan="10">W
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O
A
D</td><td rowspan="4">Contact hours</td><td>Courses</td><td>credit hours</td><td>semester load</td><td>contact time</td></tr>
<tr><td>Lectures</td><td>2</td><td>30 h</td><td rowspan="3">60 h</td></tr>
<tr><td>Exercises</td><td>1</td><td>15 h</td></tr>
<tr><td>Laboratory courses</td><td>1</td><td>15 h</td></tr>
<tr><td rowspan="3">Self study</td><td colspan="2">Form</td><td>semester load</td><td>self study</td></tr>
<tr><td colspan="2">Preparation, reworking</td><td>90 h</td><td rowspan="2">120 h</td></tr>
<tr><td colspan="2">Test preparation</td><td>30 h</td></tr>
<tr><td colspan="4">Total work load</td><td>180 h</td></tr>
<tr><td colspan="2">Credit points</td><td colspan="4">6</td></tr>
<tr><td colspan="2">Learning objectives</td><td colspan="4">The students know well the composition and the function of components, systems and applications of optical communications.

They can distinguish the different fiber types and know, which fiber should be used in a specific communication task. They have learned how to measure source spectra, how to splice fibers, how to assemble fiber connectors and how to use optical time domain reflectometry to analyse fiber links.

In summary: the students are able to design optical communication systems, to build them up and to characterize them.</td></tr>
<tr><td colspan="2">Content</td><td colspan="4">Introduction:
Historical development of optical communications, advantages and disadvantages of fiber optics

Optical basics:
The nature of light, propagation velocity, refractive index, ray optics, polarization, interference, coherence, dielectric filters

Optical fibers:
Basics, multi mode fibers, mode formation in waveguides, single mode fibers, attenuation, dispersion, bandwidth-length-product, optical cables

Fiber connection technology:
Optical splices, optical connectors, coupling losses, reflection losses

Optical transmitters and receivers:
Light emitting diodes, laser diodes, transmitter circuits, optical amplifiers, photo diodes, receiver circuits</td></tr>
</table>

	Optical measurement technology: Basic attenuation measurements, optical time domain reflectometry System technology and components: Wavelength division multiplexing technology, photonic components, integrated optics Real optical communication systems: Wide area networks, metropolitan area networks, local area networks, fibers to the customer Lab experiments: Optical sources, optical time domain reflectometry, optical splices, connector assembling and attenuation measurements
Requirements for participation	School knowledge of physics, semiconductor devices, electronic circuits
Requirements for allocation of credits	Successful pass of the written examination
Exam	Written examination
Requirements to attend the exam	Attestation of successfully finished lab experiments

10 Optical Measurement Technology

Module title		Optical Measurement Technology			
Term		3rd semester	winter		
Duration		1 semester			
Responsibility		Prof. Dr. J. Nellessen			
Lecturer		Prof. Dr. J. Nellessen			
Language		English			
Programs in which the module is used		Master of Science in Photonics		compulsory module	
WORK LOAD	Contact hours	Courses	credit hours	semester load	contact time
		Lectures	2	30 h	
		Exercises	1	15 h	
		Laboratory course	30	30 h	75 h
	Self study	Form		semester load	self study
		Lecture		45 h	
		Exercise		30 h	
		Laboratory course		60 h	135 h
				Total work load	210 h
Credit points		7			
Learning objectives		After a brief review of basic optical systems which are used in optical measurement, the students gain insight into fundamental classical measuring devices, both in theory an practical exercises. They will thus be able to determine physical properties as well as basic properties of optical systems. They will know the fundamental applications of wave optics in optical measurement (Interferometry, wave front sensing) and will be able to perform corresponding measurement tasks. After a theoretical introduction into the fundamentals of image formation, they will learn to deter-mine the imaging quality of optical systems using the concepts of the optical transfer function. Extensive practical training is given within the corresponding laboratory course.			
Content		- Review of the laws of image formation, especially two-lens-systems - Properties of the eye ; measuring with magnifiers - Microscopes - 2D- and 3D-metrology - Telescopes (align-telescopes and autocollimators) - Fundamentals of interferometric measurement ; 1D-techniques - Two-dimensional Interferometry; measuring of wavefronts, surfaces and optical system quality - Evaluation of interferograms, mathematical description - Wave front measurement (Shack-Hartmann, Foucalt, Ronchi, PSF) - Introduction to imaging theory, concept of spatial frequency and optical transfer function - Measurement of the optical transfer function			
Requirements for participation		Formally: Admission to the M. Sc. Photonics Content: Physics (I-III), technical optics			
Requirements for allocation of credits		Passing the examination			

Exam	Oral examination
Requirements to attend the exam	Successful completion of laboratory class

11 Optical Systems Design

<table>
<tr><td colspan="2">Module title</td><td colspan="4">Optical Systems Design</td></tr>
<tr><td colspan="2">Term</td><td colspan="2">1st semester</td><td colspan="2">winter</td></tr>
<tr><td colspan="2">Duration</td><td colspan="4">1 semester</td></tr>
<tr><td colspan="2">Responsibility</td><td colspan="4">Prof. Dr. J. Nellessen</td></tr>
<tr><td colspan="2">Lecturer</td><td colspan="4">Prof. Dr. J. Nellessen</td></tr>
<tr><td colspan="2">Language</td><td colspan="4">English</td></tr>
<tr><td colspan="2">Programs in which the module is used</td><td colspan="2">Master of Science in Photonics</td><td colspan="2">compulsory module</td></tr>
<tr><td rowspan="7">W
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D</td><td rowspan="3">Contact hours</td><td>Courses</td><td>credit hours</td><td>semester load</td><td>contact time</td></tr>
<tr><td>Lectures</td><td>2</td><td>30 h</td><td rowspan="2">60 h</td></tr>
<tr><td>Laboratory course</td><td>2</td><td>30 h</td></tr>
<tr><td rowspan="3">Self study</td><td colspan="2">Form</td><td>semester load</td><td>self study</td></tr>
<tr><td colspan="2">Lecture</td><td>60 h</td><td rowspan="2">120 h</td></tr>
<tr><td colspan="2">Laboratory course</td><td>60 h</td></tr>
<tr><td colspan="4">Total work load</td><td>180 h</td></tr>
<tr><td colspan="2">Credit points</td><td colspan="4">6</td></tr>
<tr><td colspan="2">Learning objectives</td><td colspan="4">The students will gain knowledge of the theoretical background of optical systems and practical experience in their development. They will be able to perform optical calculations with different methods (analytically, spread-sheet calculations and with professional optical design software). They will also be able to analyze the quality of optical systems as well es to perform optimizations tasks. Extensive practical training is given within the corresponding laboratory course.</td></tr>
<tr><td colspan="2">Content</td><td colspan="4">- Fundamentals of geometrical optics and image formation
- paraxial optics :
stops and pupils
paraxial raytracing: yu- and ynu-Method.
paraxial Invariant
- Evaluation of image quality within (ray optics, wave optics, aberrations)
- Optimization
- Aberration theory :
Seidel monochromatic aberrations
Chromatic aberrations and optical materials
- Examples of optical systems
- Gaussian beams</td></tr>
<tr><td colspan="2">Requirements for participation</td><td colspan="4">Formally: Admission to the M. Sc. Photonics
Content: Physics (I-III), fundamentals of geometrical and wave optics</td></tr>
<tr><td colspan="2">Requirements for allocation of credits</td><td colspan="4">Passing the examination</td></tr>
<tr><td colspan="2">Exam</td><td colspan="4">Homework, completed by a short oral examination of 10-15 minutes.</td></tr>
<tr><td colspan="2">Requirements to attend the exam</td><td colspan="4">Successful completion of laboratory class</td></tr>
</table>

12 Optische Funktionsmaterialien

<table>
<tr><td colspan="2">Module title</td><td colspan="4">Optische Funktionsmaterialien</td></tr>
<tr><td colspan="2">Term</td><td colspan="2">2. Semester</td><td colspan="2">Sommer</td></tr>
<tr><td colspan="2">Duration</td><td colspan="4">1 Semester</td></tr>
<tr><td colspan="2">Responsibility</td><td colspan="4">Prof. Dr. U. Kynast</td></tr>
<tr><td colspan="2">Lecturer</td><td colspan="4">Prof. Dr. U. Kynast
Prof. Dr. M. Bredol</td></tr>
<tr><td colspan="2">Language</td><td colspan="4">Deutsch</td></tr>
<tr><td colspan="2">Programs in which the module is used</td><td colspan="2">Master of Science in Photonics</td><td colspan="2">optional module</td></tr>
<tr><td rowspan="7">W
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D</td><td rowspan="4">Contact hours</td><td>Courses</td><td>credit hours</td><td>semester load</td><td>contact time</td></tr>
<tr><td>Vorlesung</td><td>2</td><td>30 h</td><td rowspan="3">75 h</td></tr>
<tr><td>Übung</td><td>1</td><td>15 h</td></tr>
<tr><td>Praktikum</td><td>2</td><td>30 h</td></tr>
<tr><td rowspan="2">Self study</td><td colspan="2">Form</td><td>semester load</td><td>self study</td></tr>
<tr><td colspan="2">Selbststudium</td><td>100 h</td><td>100 h</td></tr>
<tr><td colspan="4">Total work load</td><td>175 h</td></tr>
<tr><td colspan="2">Credit points</td><td colspan="4">6</td></tr>
<tr><td colspan="2">Learning objectives</td><td colspan="4">Konzeptbeherrschung: Optische Aktivierung bzw. Absorptions-und Relaxationsphänomene von kristallinen und amorphen Festkörpern (Dotierung, Defektchemie).</td></tr>
<tr><td colspan="2">Content</td><td colspan="4">Absorption:
Lambert-Beersches Gesetz, Kubelka-Munk-Funktion, Extinkti-ons-, Absorptionskoeffizient, Oszillatorstärke, Übergangsdipol, Übergangstypen, Farbpigmente

Relaxation:
Strahlende und nicht-strahlende Übergänge, Konfigurationskoordinatenmodell, Stokessche Verschiebung, Lumineszenz, Effizienz, Energietransfer, Phosphore

Dotierungen und Defektchemie in Kristallen und Gläsern:
Klassifizierung und Notation von Punktdefekten, Thermodynamik und Bildungsgleichungen der Defekte, Darstellung von Defekten in Bandlücken als Redox-Gleichgewichte, Diffusionsmodelle, Glasübergang, Konsequenzen für die industrielle Formgebung, Dotierung und Defektchemie in Gläsern und Kristallen</td></tr>
<tr><td colspan="2">Requirements for participation</td><td colspan="4">Abgeschlossenes Bachelorstudium Physikalische Technik</td></tr>
<tr><td colspan="2">Requirements for allocation of credits</td><td colspan="4">- Anerkennung der Ausarbeitung zum Praktikum
- Bestehen der Prüfung</td></tr>
<tr><td colspan="2">Exam</td><td colspan="4">Klausur oder mündliche Prüfung</td></tr>
<tr><td colspan="2">Requirements to attend the exam</td><td colspan="4">Anerkennung der Ausarbeitung zum Praktikum</td></tr>
</table>

13 Oral Defense of the Master Thesis

Module title		Oral Defense of the Master Thesis			
Term		4th semester		summer	
Duration		n/a			
Responsibility		A professor of the department of Applied Physics			
Lecturer		n/a			
Language		English or German			
Programs in which the module is used		Master of Science in Photonics		compulsory module	
WORK LOAD	Contact hours	Courses	credit hours	semester load	contact time
		Lectures			
		Tutorial			
		Laboratory courses			
	Self study	Form		semester load	
		Self study		150 h	
		Preparation			
		Literature Study			1 h
				Total work load	150 h
Credit points		5			
Learning objectives		The students shall learn to present the results of a complex research project in a clear manner and in a limited time. Furthermore, they shall be able to engage in a scientific discussion with the examiners.			
Content		The topic of the Master Thesis and related topics.			
Requirements for participation		At least a passing grade for the Master Thesis.			
Requirements for allocation of credits		Passing the examination.			
Exam		Oral defense.			
Requirements to attend the exam		At least a passing grade for the Master Thesis.			

14 Photovoltaik

<table>
<tr><td colspan="2">Module title</td><td colspan="4">Photovoltaik</td></tr>
<tr><td colspan="2">Term</td><td colspan="2">2. Semester</td><td colspan="2">Sommer</td></tr>
<tr><td colspan="2">Duration</td><td colspan="4">1 Semester</td></tr>
<tr><td colspan="2">Responsibility</td><td colspan="4">Prof. Dr.-Ing. Konrad Mertens</td></tr>
<tr><td colspan="2">Lecturer</td><td colspan="4">Prof. Dr.-Ing. Konrad Mertens</td></tr>
<tr><td colspan="2">Language</td><td colspan="4">Deutsch</td></tr>
<tr><td colspan="2">Programs in which the module is used</td><td colspan="2">Master of Science in Informationstechnologie
Master of Science in Photonics</td><td colspan="2">Wahlpflicht
Wahlpflicht</td></tr>
<tr><td rowspan="7">W
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D</td><td rowspan="3">Contact hours</td><td>Courses</td><td>credit hours</td><td>semester load</td><td>contact time</td></tr>
<tr><td>Vorlesung</td><td>3</td><td>45 h</td><td rowspan="2">60 h</td></tr>
<tr><td>Übung</td><td>1</td><td>15 h</td></tr>
<tr><td rowspan="2">Self study</td><td colspan="2">Form</td><td>semester load</td><td>self study</td></tr>
<tr><td colspan="2">Selbststudium</td><td>120 h</td><td>120 h</td></tr>
<tr><td colspan="4">Total work load</td><td>180 h</td></tr>
<tr><td colspan="2">Credit points</td><td colspan="4">6</td></tr>
<tr><td colspan="2">Learning objectives</td><td colspan="4">Die Studierenden sollen die Grundlagen, Zellentechnologien, Systeme und Einsatzbereiche der Photovoltaik kennen und in die Lage sein, photovoltaische Systeme zu konzipieren und zu charakterisieren.</td></tr>
<tr><td colspan="2">Content</td><td colspan="4">- Einleitung und Übersicht
- Das Strahlungsangebot der Sonne
- Grundlagen der Photovoltaik
- Zellentechnologie
- Sysemtechnik
- Photovoltaische Messtechnik
- Ökologische Rahmenbedingungen
- Zukünftige Entwicklung</td></tr>
<tr><td colspan="2">Requirements for participation</td><td colspan="4">Es wird elektrotechnisches und physikalisches Grundwissen vorausgesetzt.</td></tr>
<tr><td colspan="2">Requirements for allocation of credits</td><td colspan="4">- Anerkennung der Ausarbeitung zum Praktikum
- Bestehen der Prüfung</td></tr>
<tr><td colspan="2">Exam</td><td colspan="4">Klausur oder mündliche Prüfung</td></tr>
<tr><td colspan="2">Requirements to attend the exam</td><td colspan="4">Anerkennung der Ausarbeitung zum Praktikum</td></tr>
</table>

15 Semiconductor Technology and MOEMS Design Using FEA

<table>
<tr><td colspan="2">Module title</td><td colspan="5">Semiconductor Technology and
MOEMS-Design using the FEA</td></tr>
<tr><td colspan="2">Term</td><td colspan="2">1st and 2nd semester</td><td colspan="3">summer</td></tr>
<tr><td colspan="2">Duration</td><td colspan="5">2 semester</td></tr>
<tr><td colspan="2">Responsibility</td><td colspan="5">Prof. Dr. J. Chlebek</td></tr>
<tr><td colspan="2">Lecturer</td><td colspan="5">Prof. Dr. J. Chlebek</td></tr>
<tr><td colspan="2">Language</td><td colspan="5">English</td></tr>
<tr><td colspan="2">Programs in which the module is used</td><td colspan="3">Master of Science in Photonics</td><td colspan="2">compulsory module</td></tr>
<tr><td rowspan="10">W
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D</td><td rowspan="4">Contact hours</td><td colspan="2">Courses</td><td>credit hours</td><td>semester load</td><td>contact time</td></tr>
<tr><td colspan="2">Lectures (2+2)</td><td>4</td><td>30 + 30 h</td><td rowspan="3">105 h</td></tr>
<tr><td colspan="2">Exercises (1+0)</td><td>1</td><td>15 + 0 h</td></tr>
<tr><td colspan="2">Laboratory course (0+2)</td><td>2</td><td>0 + 30 h</td></tr>
<tr><td rowspan="4">Self study</td><td colspan="3">Form</td><td>semester load</td><td>self study</td></tr>
<tr><td colspan="3">Lecture</td><td>45 + 45h</td><td rowspan="3">165 h</td></tr>
<tr><td colspan="3">Exercise</td><td>30 + 0 h</td></tr>
<tr><td colspan="3">Laboratory course</td><td>0 + 45 h</td></tr>
<tr><td colspan="5">Total work load</td><td>270 h</td></tr>
<tr><td colspan="6"></td></tr>
<tr><td colspan="2">Credit points</td><td colspan="5">9</td></tr>
<tr><td colspan="2">Learning objectives</td><td colspan="5">The students will be able to classify already exiting microooptical devices regarding the used actuation principles and the used fabrication methods. Also they have the knowledge basis to define the flow-chart for device-manufacturing and are able to design new microoptical devices with the help of the finite elemente analysis.</td></tr>
<tr><td colspan="2">Content</td><td colspan="5">Semiconductor Technology:
- Manufacturing of single crystaline silicon
- Deposition of thin films (sputtering, LPCVD, spin on)
- Etching of thin films (physical and chemical dry etching, RIE, wet etching)
- Anisotropic etching of silicon
- Lithography (UV, electron beam)
- Electroplating (LIGA), anodic bonding
- Physical basis of micro-actuator principles
- Examples for microoptical devices

Finite Elemente Analysis:
- Introduction, Ritz's method, governing equations
- Basic procedure for calculation of static structural problems
- Transient and modal analysis
- Nonlinear calculations
- Application of the FEA to thermal, magnetostatic and electrostatic problems
- Coupled field analysis
- MOEMS as case studies</td></tr>
<tr><td colspan="2">Requirements for participation</td><td colspan="5">Formally: Admission to the M. Sc. Photonics
Content: Physics (I-III), material science, manufacturing technology and basic electrical engineering</td></tr>
</table>

Requirements for allocation of credits	Passing the examination
Exam	Oral examination of 30-45 minutes (or a written exam of 120 minutes)
Requirements to attend the exam	Successful completion of laboratory class

16 Seminararbeit / Seminar Paper

<table>
<tr><td colspan="2">Module title</td><td colspan="5">Seminar Paper</td></tr>
<tr><td colspan="2">Term</td><td colspan="2">3rd semester</td><td colspan="3">summer</td></tr>
<tr><td colspan="2">Duration</td><td colspan="5">1 semester</td></tr>
<tr><td colspan="2">Responsibility</td><td colspan="5">Prof. Dr. Ulrich Wittrock</td></tr>
<tr><td colspan="2">Lecturer</td><td colspan="5">All professors of the department</td></tr>
<tr><td colspan="2">Language</td><td colspan="5">English / German</td></tr>
<tr><td colspan="2">Programs in which the module is used</td><td colspan="3">Master of Science in Photonics</td><td colspan="2">optional module</td></tr>
<tr><td rowspan="5">W O R K L O A D</td><td rowspan="2">Contact hours</td><td>Courses</td><td>credit hours</td><td>semester load</td><td>contact time</td></tr>
<tr><td>Seminar paper</td><td>4</td><td>60 h</td><td>60 h</td></tr>
<tr><td rowspan="3">Self study</td><td colspan="2">Form</td><td>semester load</td><td>self study</td></tr>
<tr><td colspan="2">Seminar paper</td><td>120 h</td><td rowspan="2">120 h</td></tr>
<tr><td colspan="2"></td><td></td></tr>
<tr><td></td><td colspan="4">Total work load</td><td>180 h</td></tr>
<tr><td colspan="2">Credit points</td><td colspan="5">6</td></tr>
<tr><td colspan="2">Learning objectives</td><td colspan="5">The student shall study a specific, well-defined research topic. Typically, this will consist of researching the literature and learn about the state of the art of the topic. The student will then write a short review paper of about 5 pages. Writing style shall be that of a scientific review paper. As a result, the student learns how to do a thorough literature search, how to condense a large body of information into a short paper, and improve writing skills.</td></tr>
<tr><td colspan="2">Content</td><td colspan="5">The student will select a supervisor. Supervisors can be any professor from the department of Applied Physics. The topic of the seminar paper will be defined by the supervisor.</td></tr>
<tr><td colspan="2">Requirements for participation</td><td colspan="5">Formally: Admission to the M. Sc. Photonics</td></tr>
<tr><td colspan="2">Requirements for allocation of credits</td><td colspan="5">Acceptance of the paper by the supervisor.
At least a passing grade for the module examination (grade of the paper).</td></tr>
<tr><td colspan="2">Exam</td><td colspan="5">Grading of the seminar paper by the supervisor.</td></tr>
<tr><td colspan="2">Requirements to attend the exam</td><td colspan="5">Submission of the seminar paper.</td></tr>
</table>

17 Solid State Laser Engineering

<table>
<tr><td>Module title</td><td colspan="5">Solid State Laser Engineering</td></tr>
<tr><td>Term</td><td colspan="2">3rd semester</td><td colspan="3">winter</td></tr>
<tr><td>Duration</td><td colspan="5">1 semester</td></tr>
<tr><td>Responsibility</td><td colspan="5">Prof. Dr. Ulrich Wittrock</td></tr>
<tr><td>Lecturer</td><td colspan="5">Prof. Dr. Ulrich Wittrock</td></tr>
<tr><td>Language</td><td colspan="5">English</td></tr>
<tr><td>Programs in which the module is used</td><td colspan="3">Master of Science in Photonics</td><td colspan="2">compulsory module</td></tr>
<tr><td rowspan="9">W O R K

L O A D</td><td rowspan="4">Contact hours</td><td>Courses</td><td>credit hours</td><td>semester load</td><td>contact time</td></tr>
<tr><td>Lectures</td><td>2</td><td>30 h</td><td rowspan="3">75 h</td></tr>
<tr><td>Exercises</td><td>1</td><td>15 h</td></tr>
<tr><td>Laboratory (project)</td><td>2</td><td>30 h</td></tr>
<tr><td rowspan="4">Self study</td><td colspan="2">Form</td><td>semester load</td><td>self study</td></tr>
<tr><td colspan="2">Lecture</td><td>50 h</td><td rowspan="3">130 h</td></tr>
<tr><td colspan="2">Exercise</td><td>40 h</td></tr>
<tr><td colspan="2">Laboratory (project)</td><td>40 h</td></tr>
<tr><td colspan="4">Total work load</td><td>205 h</td></tr>
<tr><td>Credit points</td><td colspan="5">7</td></tr>
<tr><td>Learning objectives</td><td colspan="5">A brief review of the fundamentals of solid state lasers ensures that the students possess active knowledge and can perform calculations on their own. At the end of the course, the students are expected to be familiar with the most important concepts for solid state lasers. They have understood the tradeoffs that have to be made and how optimum solutions can be found. They should thus be able to design solid state lasers for specific applications and requirements. Extensive practical training due to exercises and the project laboratory course will also train communication skills, methods, and organizational skills.</td></tr>
<tr><td>Content</td><td colspan="5">- Rate Equations (review)
- Thermodynamics of Radiation (Black-Body Radiation, Brightness Theorem)
- Laser Gain Media
- Unsaturated and Saturated Amplification, Laser Dynamics
- Laser Efficiency Calculations
- Gaussian Beams and Beam Quality of Partially Coherent Light
- Thermal Effects in Laser Gain Media
- Concepts for Industrial and Scientific Solid State Lasers
- Phase and Intensity Noise
- Q-Switsched Lasers
- Mode-Locked Lasers</td></tr>
<tr><td>Requirements for participation</td><td colspan="5">Formally: Admission to the M. Sc. Photonics
With regard to contents: Elementary Quantum Mechanics, Laser Physics, Wave Optics</td></tr>
<tr><td>Requirements for allocation of credits</td><td colspan="5">Successful completion of laboratory class.
At least a passing grade for the module examination.</td></tr>
<tr><td>Exam</td><td colspan="5">Oral or written exam of 45 minutes and 120 minutes, respectively</td></tr>
<tr><td>Requirements to attend the exam</td><td colspan="5">Successful completion of laboratory class</td></tr>
</table>

18 Theoretical Optics

Module title		Theoretical Optics			
Term		1st semester	winter		
Duration		1 semester			
Responsibility		Prof. Dr. Klaus Morawetz			
Lecturer		Prof. Dr. Klaus Morawetz			
Language		English			
Programs in which the module is used		Master of Science in Photonics		compulsory module	
WORK LOAD	Contact hours	Courses	credit hours	semester load	contact time
		Lectures	3	45 h	75 h
		Exercises	2	30 h	
	Self study	Form		semester load	self study
		Preparation		135 h	135 h
				Total work load	210 h
Credit points		7			
Learning objectives		- knowledge of theoretical techniques of electrodynamics and quantum optics should enable the students to solve practical problems of optics - ability to apply vector analysis - basic techniques of treating quantum states			
Content		1. Laws of blackbody radiation (Stefan-Boltzmann, Wien, Rayleigh, Planck), 2. Electromagnetic waves (Maxwell equations and solutions, Fresnel formulas, metal optics, dielectrics) 3. Diffraction (Kirchhoff formula, Frauenhofer and Fresnel diffraction, Fourier optics) 4. Introduction into quantum mechanics (quantization of electromagnetic field, coherent and thermal light) 5. One-mode quantum optics (squeezed states, non-classical light) 6. Quantum information (entangled states, Bell inequalities, teleportation) 7. Introduction in statistical Optics (Entropy, distribution function, connection to thermodynamics, density operator)			
Requirements for participation		Knowledge of mathematics I-III, Fourier transform, vector calculus			
Requirements for allocation of credits		Passing of exam or defence of project work			
Exam		Written, or oral exams, or project work			
Requirements to attend the exam		none			

19 Wave and Quantum Optics

Module title	Wave and Quantum Optics				
Term	2nd and 3rd semester		summer		
Duration	2 Semester				
Responsibility	Prof. Dr. Ulrich Wittrock				
Lecturer	Prof. Dr. Ulrich Wittrock				
Language	English				
Programs in which the module is used	Master or Science in Photonics			compulsory module	
WORK LOAD	Contact hours	Courses	credit hours	semester load	contact time
		Lectures (2+2)	4	30 + 30 h	
		Exercises (1+1)	2	15 + 15 h	
		Laboratory Course (2+0)	2	30 + 0 h	120 h
	Self study	Form		semester load	self study
		Lecture		50 + 50 h	
		Exercise		30 + 30 h	
		Laboratory Course		50 + 0 h	210 h
				Total work load	330 h
Credit points	11				
Learning objectives	The students will have a good understanding of light propagation in structured media (thin films), in isotropic, and in anisotropic media. Scattering phenomena are treated on a level that is appropriate for practical work in the laboratory. An introduction to coherence theory and adaptive optics is given at the end of the WAVE OPTICS course. In the QUANTUM OPTICS course, the naïve view of photons as particles will be corrected. Applied topics are nonlinear optics, phase and amplitude noise, laser frequency stabilization, and a case study which encompasses almost all themes covered in this module. The students will appreciate the counter-intuitive aspects of quantum optics and loose their resentments towards abstract concepts that are required in modern physics.				
Content	WAVE OPTICS: - Matrix Formalism for Calculating Transmission and Reflection of Dielectric Thin Film Stacks - Thin Film Systems and their Application - Surface Scattering - Harmonic Oscillator Model for the Refractive Index - Volume Scattering (Rayleigh, Mie, Brillouin, Raman) - Wave Propagation in Anisotropic Media (Uniaxial and Biaxial) - Induced Anisotropy (Faraday, Kerr, Pockels) - Stokes Parameters, Mueller Matrices, Jones Vectors and Jones Matrices - Introduction to Coherence Theory - Adaptive Optics				

	QUANTUM OPTICS: - Nonlinear Susceptibility - Phase Matching - Optical Parametric Amplifiers and Oscillators - Interferometric Autocorrelation for Measuring Ultrashort Pulses - Nonlocal Nature of the Quantum World (Einstein-Podolski-Rosen Experiment) - Quantum Cryptography - Interaction-Free Measurements - Second Quantization - Photon Statistics - Nonclassical Light - Pound-Drever-Hall Laser Frequency Stabilization - Case Study: Atmospheric Dynamics Mission AEOLUS - Laser Spectroscopy: Doppler-Free Spectroscopy
Requirements for participation	Formally: Admission to the M. Sc. Photonics. With regard to contents: Elementary Quantum Mechanics, Laser Physics, Wave Optics.
Requirements for allocation of credits	Successful completion of laboratory class. At least a passing grade for the module examination.
Exam	Oral or written exam of 45 minutes and 120 minutes, respectively.
Requirements to attend the exam	Successful completion of laboratory class.