



STUDIENDEKANAT
MASCHINENBAU



Module Catalog for PO 2017

Study Guide for the study program
Optical Technologies
Master of Science

academic year 20/21



Faculty of Mechanical Engineering



Course and Module Catalogue

for Examination Regulations 2017

**Optical Technologies:
Photonics and Laser Technology**

Master of Science

academic year 2020/21

This course and module catalogue is also available on the website of the
Faculty of Mechanical Engineering: <http://www.maschinenbau.uni-hannover.de/>

Impressum

Dean of Studies office – Faculty of Mechanical Engineering of the Leibniz
Universität Hannover

www.maschinenbau.uni-hannover.de

Valid for the winter semester 2020/2021

Hannover, 23.09.2020

Responsible:

Prof. Dr. M. Becker

Contacts:

Lisa Lotte Schneider, M. Sc.

Address:

An der Universität 1
DE-30823 Garbsen

Telephone:

+49 (0)511 762-17519

E-Mail:

opticaltechnologies@maschinenbau.uni-hannover.de

Contents

Contents1

Introduction.....2

 Master's degree program Optical Technologies3

 Study profile3

 Educational goals of the master’s degree course optical technologies –
 Knowledge, Skills, Competence.....4

 Didactic results4

 Studium Generale.....5

 Master Lab.....5

 Tutorial5

 Student Project.....5

 Initial Internship6

 Advanced Internship6

 Master Thesis7

Master’s degree plan.....7

 Master’s degree plan.....8

Program Description.....9

 Personal Prerequisites.....9

Compulsory and Optional Modules.....10

Course Descriptions14

Introduction

Dear Students,

Hereby, you receive the current module catalogue of the Master Course “Optical Technologies”. This course was established by the Faculty of Mechanical Engineering as well as the Faculty of Mathematics and Physics in cooperation with the Laser Zentrum Hannover e.V. in order to strengthen and promote the field of optical technologies in science and research in Hannover.

With this new master course you receive an education, which combines cutting edge basic and applied research in the fields of optics and photonics, physics and engineering and thus qualifies you for both the optics industries and academic research. In combination with your educational background - Bachelor of Science or Bachelor of Engineering – you acquire skills to apply scientific theory in research practice.

If required, the Office of Student Affairs supports you in planning and organizing your study. Do not hesitate to make use of this possibility. Furthermore, you will receive support from experienced students, scientific staff members of the institutes and the Hannover Centre for Optical Technologies (HOT).

We wish you the best for your studies,

Prof. Dr. M. Becker

Dean of studies of the faculty of mechanical engineering.

Master's degree program Optical Technologies

The standard period of study is four semesters of which one semester is for the master thesis. Overall, 120 credit points (CP) are to be achieved, which are split into the following individual modules:

Basic courses

Optional courses

Master Lab

Studium Generale and Tutorials

Student Project

Advanced Internship (12 weeks)

Master Thesis

Study profile

The master's degree program has the goal to train professionals and executives for the entire optics industry with a focus on "German Agenda Optical Technologies for the 21st Century".

On the national scale, Lower Saxony is already well positioned in the teaching of optics and photonics. Favorable conditions are specifically given in Hanover as a particularly close cooperation between the basic disciplines engineering and physics is well established. Furthermore, the Laser Zentrum Hannover constitutes a link between academic research and industry to involve the industrial partners in the current research and science and introduces academic students to the industry.

This interdisciplinary master's degree program is not primarily associated with only one faculty but combines the fundamental skills of the Faculty of Mathematics and Physics with the application knowledge of engineering.

Educational goals of the master's degree course optical technologies – Knowledge, Skills, Competence

It is expected from the future professionals in optics and photonics to not only be able to solve tasks and problems on the basis of engineering methods but also to have knowledge on the important basic principles of optical technologies.

This is ensured by corresponding compulsory courses offered in the master's Degree program. The theoretical and practical training in physics is completed with specific topics in engineering, which can be selected from different competence areas. Practical training in the context of laboratory tests and an internship in an industrial area prepares the students for their professional activity in research based companies of the optical industry.

In addition, the Student Project and the master thesis help students to acquire skills for the independent handling of projects. Gaining experience in the planning and implementation of projects and the transfer of knowledge for the preparation of a proper project documentation and presentation of the project results are also among the primary objectives of this work. Building on the physical and engineering skills taught during the courses, the graduates are empowered to solve tasks and problems in the field of optical technologies. A target matrix of the master's degree program can be found in the appendix.

Didactic results

Graduates of the master's degree program will acquire a broad knowledge in the field of optical technologies. Thus, the program teaches knowledge, skills and methods, which, due to the faculties' high proportion of research, represent the state-of-the-art in optics and photonics. Due to the internship in the field of industry, practical laboratory work as well as Student Project and master thesis, experience in project management, teamwork and scientific care in research activities can be gained.

Studium Generale

The Studium Generale serves the extra-professional qualification of the students. All courses at Leibniz University are recognized as part of this module. Courses for the student's native language as well as language courses below the course requirements are not credited.

Master Lab

The objective of the master lab is the practical application and consolidation of the theoretical knowledge gained in the attended lectures and exercises. The master lab includes experiments in mechanical engineering and physics but also in the fields of computer science and electrical engineering.

Several practical experiments are carried out, which are managed by the participating institutes. Although under supervision, the tests are carried out independently by student teams. Dates and registration details will be announced by the respective institutes. For organization and further information please contact lea.domke@phoenixd.uni-hannover.de.

Tutorial

Tutorials are used for conveying of key competences. Most tutorials include approximately 25 hours of attendance time or self-study time, corresponding to a 3-day seminar. Skills are taught in the fields of scientific research, media presentation, self and team organization, or the handling of scientific software.

The tutorial program will be expanded continuously. It can be picked up in the office of the dean of the faculty of mechanical engineering as either print or pdf version. Dates and registration details will be announced by the respective institutes.

Student Project

In the Student Project, students learn to work with a scientific task independently. From literature research to problem solving and subsequent presentation, the students will be introduced to working in the scientific field. The project requires a processing time of 300 hours. This corresponds to approximately 7.5 40h-weeks.

Initial Internship

The Initial Internship enables students to gain their first experience of industry. Within a working environment of experts, students, teachers and technical personnel, the student is able to develop practical knowledge of varied manufacturing processes and facilities.

The Initial Internship lasts 8 weeks and may be combined with the Advanced Internship.

If applicable, internships already completed or previous vocational training or activity may be credited. Further details are defined by the Internship Regulations and the Internship Office of the Faculty.

Advanced Internship

The Advanced Internship prepares students for the productive cooperation in research based companies in the optical industry and in companies of other industries that use optics for quality control in the production or as part of a total product.

During the internship, the focus is laid on work which is closely related to the field of engineering within a development team or a research and development area. Usually, the student receives a subtask which he will work on, document, and present after proper training in the course of the internship.

The Advanced Internship lasts twelve weeks. Internships already completed can be credited. Further details are defined by the Internship Regulations and the Internship Office of the Faculty. In the case of previously completed internship, courses in the area of elective and elective courses with a total volume of 15 CP must be taken instead.

Master Thesis

The students have the opportunity to participate in an international research environment, and to work on a relevant scientific problem independently in accordance with a project plan developed by them. This includes the execution of respective experiments and calculations as well as the evaluation of their results. The students are able to document their work according to the problem and results in written form, and present and discuss it in a suitable way. Despite the expertise needed for this performance, they will, furthermore, improve their methodological skills, team skills, and self-competence.

The Master's degree thesis has a processing time of 900 hours. This corresponds to about 22.5 40-hour weeks.

Master's degree plan

This section shows the attribution of the courses to the four semesters of the master's degree program in Optical Technologies.

Master's degree plan

CP	1 st term	2 nd term	3 rd term	4 th term
1	Photonics Compulsory Module (5 CP)	Design and Simulation of optomechatronic Systems Compulsory Module	Student Project (10 CP)	Master Thesis (30 CP)
2				
3				
4				
6	Optical Measurement Technology Compulsory Module (5 CP)	Optional Modules (20 CP)	Advanced Internship (15 CP)	
7				
8				
9	Laser Spectroscopy in Life Sciences Compulsory Module (5 CP)			
10				
11	Optional Modules (15 CP)			
12				
13				
14				
16				
17				
18				
19				
20				
21				
22	Master Lab Tutorial (5 CP)	Project Pres. (1 CP)	Studium Generale / Tutorials (4 CP)	
23				
24				
26				
27				
28				
29				
Σ				

Program Description

The Master of Science in Optical Technologies program is offered by the faculties of mechanical engineering and mathematics and physics and is coordinated by the faculties of mechanical engineering at the Leibniz University Hannover. It provides students with scientific knowledge and research training in optics and photonics. The program prepares students for seeking employment in industry and academia in areas as diverse as optical technologies, product development, and commercialization.

The study program includes a balanced course including interdisciplinary scientific courses and research training in the field of optical technologies, which is widely used in industry, telecommunications and modern consumer devices, ranging from the tiny lasers in many disc drives to the thousands of kilometers of optical fibers carrying signals between continents.

Admissions to the program occur both in the winter and summer term of each year and students are expected to finish the degree within two years. Upon successful completion of the program, the student is awarded a Master of Science (M.Sc.) degree.

Personal Prerequisites

Great interest in optical problems is certainly necessary; however, very good skills in physics and engineering or related areas are indispensable. Also, a systematic description of optical phenomena is not possible without mathematical formulations. Therefore, mathematical skills are also recommended. Abstraction abilities, inter- and transdisciplinary thinking and the ability to think and work logical are also helpful.

Essentially, the program is intended for students with a Bachelor of Science (B. Sc.) degree in mechanical engineering or physics or related area.

Compulsory and Optional Modules

Postgraduate students must ensure that they have a total of 120 Credits.

Compulsory Modules

Module	Responsible	Sem.	Credits
Optical Measurement Technology	Reithmeier	WS	5
Laser Spectroscopy in Life Sciences	Roth	WS	5
Design and Simulation of optomechatronic Systems	Lachmayer	SS	5
Photonics	Chichkov	WS	5

Optional Modules (OM)

Module	Responsible	Sem.	Credits
Atomic Optics	Ospelkaus	SS	4
Atom Optics for Optical Technologies	Rasel,	SS	5
Automotive Lighting	Wallaschek, Lachmayer	WS	5
Biophotonics – Imaging Physics and Manipulation of Biological Cells	Heisterkamp	SS	4+1
Computational Photonics	Demircan	SS	6
Optical Radiometry	Kovacev	SS	-
Fundamentals and Configuration of Laser Beam Sources	Wienke	WS	5
Fundamentals of Laser Medicine and Biophotonics	Lubatschowski, Heisterkamp	WS	4
Laser Interferometry	Heinzel	WS	2
Laser Material Processing	Overmeyer	SS	5
Laser Measurement Technology	Roth	SS	5
Non-linear Optics	Morgner	SS	5
Optical 3D-Measurement	Wiggenhagen	SS	5
Optical Coatings and Layers	Ristau	WS	4+1
Photogrammetric Computer Vision	Heipke	WS	5
Production of Optoelectronic Systems	Overmeyer	WS	5
Proseminar Biophotonics	Roth, Morgner	WS	3
Radar Remote Sensing	Motagh	WS	3
Remote Sensing I	Melsheimer	WS	4
Remote Sensing II	Melsheimer	WS	4

Optional Modules (OM)

Module	Responsible	Sem.	Credits
Seminar Numerical Optics	Demircan	SS	3
Seminar Optics at Femto- and Attosecond Scales	Morgner, Kovacev	WS	3
Seminar Theory and practice of optical functional layers	Ristau	SS	3
Solid State Lasers	Weßels	SS	2
Ultrashort Laser Pulses	Morgner	SS	2
Applied Wave Optics	Caspary	WS/SS	4
Laserscanning – Modelling and Interpretation	Brenner	WS	5
Spray Technology	Kawaharada	WS	3
Optical properties of Micro- and Nanostructures	Cala' Lesina	WS	5
Introduction to Nanophotonics	Cala' Lesina	SS	5

Additional Mandatory Modules

For all students who require additional mandatory modules. There are two modules available which replace the mandatory lectures as follows:

Module	Responsible	Sem.	Credits
Solid State Lasers Replaces the mandatory modules: <ul style="list-style-type: none"> • Einführung in die Festkörperphysik <i>This module can only be acknowledged once! Students who are affected have to attend an additional course to match their ECTS-goal!</i>	Weßels	SS	/
Optics, atomic and quantum physics Replaces the mandatory modules: <ul style="list-style-type: none"> • Optik, Atomphysik, Quantenphänomene • Atom- und Molekülphysik • Moleküle, Kerne, Teilchen, Festkörper 	Morgner	WS	/

Course Descriptions

In this chapter, the descriptions of the individual courses (compulsory and elective) follow. For each course the course title as listed in the lecture list, the type of lecture, the course number, the responsible lecturer, the corresponding institute and a contact address in case of questions can be taken.

A short descriptive text is followed by the indication of study time as well as the ECTS credits to be awarded, which are to be evaluated as follows:

Presence and Self-Study time

The presence- or self-study time indicates how many hours the student has to invest in the course. The time the student actively participates in the lecture is considered to be the presence-time. The time it takes for the student to work up the content on his own or to work through the exercises is considered to be the self-study time.

ECTS-CP

The ECTS credit points are a measure of the processing time that students invest in a course. According to the stipulations of the Conference of Ministers of Education, one (1) ECTS-CP will be awarded per 25-30 hours of study time.

Course Volume

One semester week hour means 45 minutes of the course per week during the lecture period (around 14 to 15 weeks per semester)

- L: Lecture
- E: Exercise
- La: Laboratory
- S: Seminar

Type of Examination

Written or oral exams are administered by the teaching professor.

Modulname	Applied Wave Optics						
Modulname EN	Applied Wave Optics						
Verantw. Dozent/-in	Caspary				Semester	Wi-/SoSe	
Institut	Cluster of Excellence PhoenixD				ECTS	4	
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien						
Vertiefungsrichtung	Optional Modules				Prüfungsform	schrift./münd.	
Präsenzstudienzeit	21	Selbststudienzeit	99	Kursumfang	L2		

Modulbeschreibung

This lecture starts with a fast introduction to wave optics. It covers the theory from Maxwell's equations to subjects like the Kramers-Kronig relationship or birefringence. Two important examples for basic applications are transversal modes in dielectric optical waveguides and longitudinal modes in laser resonators. The lecture will also contain some special examples of wave optics in the field of optical technologies like photonic crystals, plasmonic devices, and holography.

Content:

- Maxwell's equations, Fresnel equations and Huygens principle
- Wave guiding and transversal modes
- Mode solving and mode coupling
- Resonators and longitudinal modes
- Lasers and coherence
- Photonic crystals
- Plasmonics
- Holography

Vorkenntnisse

Electromagnetism, Maxwell's equations, geometrical optics.

Literatur

F. A. Jenkins, H. E. White: Fundamentals of Optics; K. J. Ebeling: Integrated Optoelectronics; F. K. Kneubühl, M. W. Sigrist: Laser

Besonderheit

Recommended for first semester and higher of master courses in Physics or Optical Technologies.

Modulname	Atomoptik		
Modulname EN	Atomic Optics		
Verantw. Dozent/-in	Ospelkaus	Semester	SoSe
Institut	Institut für Quantenoptik	ECTS	4
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schrift./münd.
Präsenzstudienzeit	32	Selbststudienzeit	88
	Kursumfang	V2/E1	

Modulbeschreibung

Recent experimental procedures to investigate the physics of ultracold gases, laser manipulation of single atoms and quantum engineering are discussed experimentally and theoretically. Students will gain insight in recent developments in the field of atomic physics.

Contents:

- Matter-light interaction
- Radiation pressure
- Atom- and ion traps
- Cooling by evaporation
- Bose-Einstein condensation
- Ultracold Fermi gases
- Experiments based on ultracold and degenerated gases
- Atoms in periodic optical gratings
- ATOMICS and modern atomic physics experiments

Vorkenntnisse

Atom and Molecular Physics, Quantumoptics

Literatur

B. Bransden, C. Joachain, „Physics of Atoms and Molecules“, Longman 1983
R. Loudon, “The Quantum Theory of Light“, OUP 1973
Van der Straaten

Besonderheit

The course's name on Stud.IP is "Atomoptik"

Modulname	Atomoptik für Optische Technologien		
Modulname EN	Atom Optics for Optical Technologies		
Verantw. Dozent/-in	Dozenten der Quantenoptik, Schlippert, Rasel	Semester	SoSe
Institut	Institut für Quantenoptik	ECTS	5
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schrift./münd.
Präsenzstudienzeit	32	Selbststudienzeit	118
		Kursumfang	V2/U1

Modulbeschreibung

The aim of this lecture course is the introduction of engineering students to the basic principles of atom optics. As a foundation, the fundamental aspects and concepts of quantum mechanics, such as wave functions, Schrödinger equation and the principle of superposition are provided. Afterwards, fundamental and technological aspects and applications of matter wave interferometers are discussed and put into context with their optical analogons.

The exercise course aims at consolidating the understanding of the basic principles and provides theoretical exercises according to selected example applications and delivers intensified direct context to quantum optics laboratories.

Contents:

- Foundations of quantum mechanics
- Mathematical methods
- Wave functions & Schrödinger equation
- Principle of superposition Matter wave interferometry
- Fundamental aspects, atom-light interaction
- Technological aspects, e.g. in the context of noise in atom interferometers
- Applications
- Matter wave interferometry
- Fundamental aspects, atom-light interaction
- Technological aspects, e.g. in the context of noise in atom interferometers
- Applications

Vorkenntnisse

Basics of laser physics and laser technology, "Optik, Atomphysik und Quantenphänomene" (Exphy 3)

Literatur

Metcalf & van der Straten, Laser cooling and trapping, Springer-Verlag 2002

Besonderheit

Recommended for second semester and higher (Master course)

Modulname	Automotive Lighting				
Modulname EN	Automotive Lighting				
Verantw. Dozent/-in	Wallaschek, Lachmayer			Semester	WiSe
Institut	Institut für Dynamik und Schwingungen			ECTS	5
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien				
Vertiefungsrichtung	Optional Modules			Prüfungsform	schrift./münd.
Präsenzstudienzeit	32	Selbststudienzeit	88	Kursumfang	V2

Modulbeschreibung

The course offers an introduction into automotive lighting technology and teaches the technological and physiological fundamentals which are necessary to understand and evaluate lighting systems. In addition to the required optical variables the state of the art and future trends of automotive lighting will be presented. Important technologies like for example new light sources and their application in automotive front and signal lights as well as in further optical systems will be considered. One main aspect of the lecture focusses on light-based driver assistance systems (e.g. glare free high beam, marking light) which are one core aspect of today's technological development. Physiological and psychological basics like the structure of the human eye and the visual system complete the course.

Contents:

- Light sources, headlights, rear lights
- Mechanical and electrical components
- Light-based driving assistance systems
- Visual system of humans
- Structure of the human eye
- Photopic, mesopic and scotopic vision
- Disability and discomfort glare
- Environment sensor systems
- Image processing
- Active lighting systems

Vorkenntnisse

none

Literatur

Wördenweber, B., Wallaschek, J.; Boyce, P.; Hoffman, D.: Automotive Lighting and Human Vision, Springer-Verlag, Berlin, Heidelberg 2007
Gregory, R. L.: Eye and Brain: The psychology of seeing, 5. ed., Oxford Univ. Press, 1998

Besonderheit

The course language is English. The course consists of two parts: 1. An introductory part on the basics of lighting technology (2 lectures) and on human vision and visual perception (1 lecture) 2. A further lecture part on current topics in automotive lighting technology (3 lectures)

Modulname	Biophotonik - Bildgebung und Manipulation von biologischen Zellen				
Modulname EN	Biophotonics - Imaging Physics and Manipulation of Biological Cells				
Verantw. Dozent/-in	Heisterkamp			Semester	SoSe
Institut	Institut für Quantenoptik			ECTS	4+1
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien				
Vertiefungsrichtung	Optional Modules			Prüfungsform	schrift./münd.
Präsenzstudienzeit	32	Selbststudienzeit	88	Kursumfang	V2/Ü1/P1

Modulbeschreibung

Within the lecture "Biophotonics" laser technologies and optical methods will be introduced, which are applied within modern cell biology, regenerative medicine and the field of tissue engineering. Especially laser based imaging technologies, applied at the cellular level, will be covered, as well as tissue characterization and 3D volumetric imaging. This includes the fundamentals of microscopical imaging, different contrast mechanisms and optical clearing, as well as optical coherence tomography, and laser scanning microscopy and super resolution approaches. Furthermore, application within biotechnology, such as biochips, cell sorting and cell surgery and interaction with nanoparticles and nanostructures will be discussed.

The students will acquire knowledge within this interdisciplinary field of physics, engineering, life science and medicine. The covered areas will be exemplarily discussed using examples of current research themes investigated at joint projects with the MHH and the excellence cluster REBIRTH (From Regenerative Biology to Reconstructive Therapy). Aside from teaching the fundamentals and facts of biophotonics, the lecture introduces the students to the search and understanding of original research articles. With each topic covered within the lecture, recent articles from research journals will be discussed in monthly tutorials. In one of these tutorials the article search using internet search engines will be covered (at the RRZN). The other tutorials will take place at the seminar room of theIQ, in which the relevant article will be discussed.

Vorkenntnisse

Basic knowledge in coherent optics, Possibly Fundamentals of Lasers in Medicine and Biomedical Optics (WS), Laserphysics

Literatur

Prasad, Paras N.: Introduction to Biophotonics. John Wiley & Sons 2003. Jürgen Popp: Handbook of Biophotonics, Volume 1: Basics and Techniques, Jürgen Popp (Editor), Valery V. Tuchin (Editor), Arthur Chiou (Editor), Stefan H. Heinemann (Editor), ISBN: 978-3-527-41047-7 (TIB-Signatur: T 12 B 5852) Min Gu: Femtosecond Biophotonics: Core Technology and Applications. Cambridge University Press, 2010. ISBN: 0521882400 (TIB-Signatur: T 10 B 5962) Adam Wax: Biomedical Applications of Light Scattering, New York, NY [u.a.] : McGraw-Hill, 2010, ISBN: 978-0-07-159880-4 (TIB-Signatur: T 09 B 8078)

Besonderheit

To reach the 5 LP you have to pass an exam (4LP) and a presentation (1LP). In addition to the lecture tutorials are offered in monthly intervals regarding e.g. literature research on the internet, Fourier transformation or image processing. The course's name on Stud.IP is "Biophotonik - Bildgebung und Manipulation von biologischen Zellen"

Modulname	Computational Photonics		
Modulname EN	Computational Photonics		
Verantw. Dozent/-in	Demircan	Semester	SoSe
Institut	Institut für Quantenoptik	ECTS	6
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schriftlich
Präsenzstudienzeit	56	Selbststudienzeit	94
	Kursumfang	V2/U2	

Modulbeschreibung

The lecture is organized in two parallel-running tracks: Photonics Fundamentals, and Numerical Methods. The course has a practical exercise component providing the student with basic computer simulation experience.

Topic:

- Light-matter interaction (Chromatic and geometric dispersion, second and third-order susceptibility, Raman scattering, supercontinuum generation, multiphoton and tunneling ionization, low-order harmonic radiation)
- Light transport in turbid media
- Photoacoustics
- Matrix optics
- Pulse propagation equations
- Atoms in strong optical fields (Schrödinger equation for atoms, Higher-Harmonic generation, Brunel/THz radiation, attosecond optics)
- Computer modeling methods in electromagnetics (Time-domain solvers, frequency domain methods, finite element methods)
- Monte Carlo method
- Spectral and Pseudospectral methods
- Runge-Kutta and operator splitting approach
- Parallel computing (openMP, openMPI)

Vorkenntnisse

keine

Literatur

Obayya: Computational Photonics; Joachain/Kylstra/Potvliege: Atoms in Intense Laser fields; Lux/Koblinger: Monte Carlo Particle Transport Methods: Neutron and Photon Calculations

Besonderheit

Prüfungsleistung: Die Note ergibt sich aus 40% der Bewertung der Leistungen in den Computerübungen und 60% der Klausurnote.

Modulname	Design and Simulation of optomechatronic Systems		
Modulname EN	Design and Simulation of Optomechatronik Systems		
Verantw. Dozent/-in	Lachmayer, Wolf, Wolf	Semester	SoSe
Institut	Institut für Produktentwicklung und Gerätebau	ECTS	5
Art	<input checked="" type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung		Prüfungsform	schriftlich
Präsenzstudienzeit	40	Selbststudienzeit	110
		Kursumfang	V3/U1

Modulbeschreibung

Qualifikation: In the lecture design and simulation of optomechatronic systems the construction, manufacturing and dimensioning of optical devices will be handled. This English lecture is especially designed for master students of optical technologies.

Goals: The students get to know the fundamentals of lighting technology can describe the physiology of the human visual system get to know optical materials (glasses and polymers) and the according manufacturing and processing technologies learn the analytical calculation of simple optical elements such as mirrors and lenses set up concepts for optical systems use an optical simulation software learn the working principle of light measurement devices can analyze existing optical systems

Vorkenntnisse

Literatur

Umdruck zur Vorlesung

Besonderheit

Vorlesung ist auf Englisch. This lecture is given in english. Alter Titel: "Konstruktion Optischer Systeme / Optischer Gerätebau". Old heading: "Konstruktion Optischer Systeme / Optischer Gerätebau"

Modulname	Festkörperlaser		
Modulname EN	Solid State Lasers		
Verantw. Dozent/-in	Weßels	Semester	SoSe
Institut	Institut für Quantenoptik	ECTS	2
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung		Prüfungsform	schrift./münd.
Präsenzstudienzeit	32	Selbststudienzeit	32
		Kursumfang	V2

Modulbeschreibung

Within this lecture the fundamentals needed for the understanding of modern solid state lasers will be developed. In particular, the optical properties and typical parameters of different solid state laser designs will be developed. Furthermore, the application potential of the various solid laser designs will be treated. Contents:

- Solid state laser media
- optical resonators
- laser modes of operation
- diode pumped solid state lasers
- laser designs: fiber, rod, disc; tunable lasers
- single-frequency lasers
- ultrashort-pulse lasers/frequency conversion

Vorkenntnisse

Basic knowledge in physics and coherent optics.

Literatur

W. Koechner: Solid-State Laser Engineering, A. E. Siegman: Lasers, O. Svelto: Principles of Lasers.

Besonderheit

This course is equivalent to the german taught module "Fundamentals and Configuration of Laser Beam Sources". Only one of these modules may be credited for the master course, respectively.

Modulname	Fundamentals and Configuration of Laser Beam Sources		
Modulname EN	Fundamentals and Configuration of Laser Beam Sources		
Verantw. Dozent/-in	Wienke	Semester	WiSe
Institut	Institut für Transport- und Automatisierungstechnik	ECTS	5
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schrift./münd.
Präsenzstudienzeit	40	Selbststudienzeit	110
		Kursumfang	V2

Modulbeschreibung

The lecture gives an overview of different types of laser beam sources. In the basic part the concepts for the generation of laser radiation in various active media for different applications as well as requirements for optical resonators are presented. Different pumping schemes and concepts are discussed for the various laser systems, especially gas-, diode and solid-state lasers. In addition, the operating modes continuous, pulsed and ultrashort pulsed will be explained in more detail. Based on the basic considerations and concepts, real laser beam sources are presented and analyzed. The following contents will be taught in the course and through demonstrations: basics of laser beam sources, operation modes of lasers, laser characterization, laser diodes, optical resonators, CO₂ lasers, excimer lasers, laser concepts and laser materials, rod lasers and disk lasers, fiber lasers and amplifiers, frequency conversion, lasers for space applications and ultrashort pulse lasers.

Vorkenntnisse

Literatur

Besonderheit

Die wöchentliche Vorlesung findet im Laser Zentrum Hannover e.V. (LZH) Hollerithallee 8 30419 Hannover. Die Vorlesung wird in englischer Sprache gehalten.

Modulname	Fundamentals of Laser Medicine and Biophotonics				
Modulname EN	Fundamentals of Laser Medicine and Biophotonics				
Verantw. Dozent/-in	Heisterkamp, Lubatschowski			Semester	WiSe
Institut	Institut für Quantenoptik			ECTS	4
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien				
Vertiefungsrichtung	Optional Modules			Prüfungsform	mündlich
Präsenzstudienzeit	32	Selbststudienzeit	118	Kursumfang	L2

Modulbeschreibung

The lecture explains laser medicine with basics from biophotonics. The laser principle, types of medical lasers and their effects on biological tissue are presented. As current clinical application, laser surgery of the eye based on ultrashort pulse lasers is discussed.

After a fundamental introduction to tissue optics with its various absorption and scattering processes, imaging techniques such as optical coherence tomography (OCT) and two-photon microscopy will be explained. After the lecture, an excursion with laboratory and company visit is offered.

Contents:

- Laser systems for the application in medicine and biology
- Beam guiding systems and optical medical devices
- Optical properties of tissues
- Thermal properties of tissues
- Photochemical interaction
- Vaporization/coagulation
- Photoablation, optoacoustics
- Photodisruption, nonlinear optics
- Applications in ophthalmology, refractive surgery
- Laser-based diagnostics, optical biopsy
- Optical coherence tomography, theragnostic
- Clinical examples

Vorkenntnisse

Coherent Optics, Photonics or Nonlinear Optics

Literatur

Eichler, Seiler: "Lasertechnik in der Medizin"; Springer-Verlag Welch, van Gemert: "Optical-Thermal Response of Laser-Irradiated Tissue"; Plenum Press Berlin, Müller: "Angewandte Lasermedizin"; Bd. 1,2, eco med Verlag Berlin, Müller: "Applied Laser Medicine"; Springer-Verlag Berns, Greulich: "Laser Manipulation of Cells and Tissues"; Academic Press

Besonderheit

Examination: The students present current publications in the field within the scope of a block seminar. This will be followed by an examination on the publication and on lecture contents. Study achievement: Participation in lecture and block seminar.

Modulname	Grundlagen und Aufbau von Laserstrahlquellen		
Modulname EN	Fundamentals and Configuration of Laser Beam Sources		
Verantw. Dozent/-in	Overmeyer, Kracht	Semester	WiSe
Institut	Institut für Transport- und Automatisierungstechnik	ECTS	5
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schrift./münd.
Präsenzstudienzeit	40	Selbststudienzeit	110
		Kursumfang	V2/U1

Modulbeschreibung

Die Vorlesung vermittelt einen Überblick über verschiedene Arten von Laserstrahlquellen. Es werden dabei im Grundlagenteil die Konzepte zur Erzeugung von Laserstrahlung in verschiedenen Medien für unterschiedliche Einsatzbereiche sowie Anforderungen an optische Resonatoren präsentiert. Für die unterschiedlichen Lasertypen werden die, insbesondere zwischen Gas-, Dioden- und Festkörperlasern, teilweise stark unterschiedlichen Pumpkonzepte diskutiert. Darüber hinaus werden die Betriebsregime kontinuierlich, gepulst, ultrakurzgepulst näher erläutert. Ausgehend von den grundlegenden Betrachtungen und Konzepten werden jeweils auch reale Laserstrahlquellen vorgestellt und analysiert. Folgende Inhalte werden in der Lehrveranstaltung und durch Demonstrationen vermittelt: Grundlagen Laserstrahlquellen, Betriebsregime von Lasern, Lasercharakterisierung, Laserdioden, Optische Resonatoren, CO₂-Laser, Eximerlaser, Laserkonzepte und Lasermaterialien, Stablasers und Scheibenlaser, Faserlaser und Verstärker, Frequenzkonversion, Laser für Weltraumanwendungen und Ultrakurzpuls laser.

Vorkenntnisse

Grundlagen der Optik

Literatur

Vorlesungsskript; Weitere Literatur wird in der Vorlesung angegeben.

Besonderheit

Keine

Modulname	Introduction to Nanophotonics		
Modulname EN	Introduction to Nanophotonics		
Verantw. Dozent/-in	Cala Lesina	Semester	SoSe
Institut	Hannoversches Zentrum für Optische Technologien	ECTS	5
Art	<input type="checkbox"/> Pflicht <input checked="" type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung		Prüfungsform	schrift./münd.
Präsenzstudienzeit	52	Selbststudienzeit	98
		Kursumfang	V2/U2

Modulbeschreibung

Nanophotonics (also known as nano-optics) studies the behavior of light on the nanometer-scale, and the effect of its interaction with nanostructures. This course provides an introduction to nanophotonics, with a focus on material optical properties arising from nano-scale effects.

After successfully completing the module, students are able to
(Qualification goals)

- Understand the optical properties of metals and the theory of plasmonic resonances.
- Understand the theory of the scattering of light from a sphere (Mie theory) and calculate absorption/scattering and extinction coefficients.
- Understand how metasurfaces work, and design a distribution of sub-wavelength emitters for light structuring/shaping.
- Calculate analytically/numerically the reflectance/transmittance by a multi-layer.
- Simulate a basic nanophotonic problem.

Module content

- Optical properties of metals, fundamentals of plasmonics.
- Light scattering by metallic and dielectric nanoparticles.
- Metasurfaces and light manipulation at the nanoscale.
- Multi-layer systems and nano-films.
- Modelling and simulation in nanophotonics.

Vorkenntnisse

Optics and waves (Maxwell's equations, plane wave propagation).

Literatur

Novotny, L., & Hecht, B. (2012). Principles of Nano-Optics (2nd ed.). Cambridge: Cambridge University Press. Gaponenko, S. (2010). Introduction to Nanophotonics. Cambridge: Cambridge University Press.

Besonderheit

Modulname	Laser Material Processing		
Modulname EN	Laser Material Processing		
Verantw. Dozent/-in	Overmeyer	Semester	SoSe
Institut	Institut für Transport- und Automatisierungstechnik	ECTS	5
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schriftlich
Präsenzstudienzeit	40	Selbststudienzeit	110
	Kursumfang	V2/U2	

Modulbeschreibung

The module provides basic knowledge about the spectrum of laser technology in production as well as the potential of laser technology in future applications. After successful completion of the module, the students are able

- to classify the scientific and technical basics for the use of laser systems and the interaction of the beam with different materials,
- to recognize the necessary physical requirements for laser processing and to select specific process, handling and control technology for this purpose, -to explain the basic and current requirements for laser technology in production technology,
- to estimate the process variables that can be realized by means of laser material processing.

Content :

- Photonic system technology
- Beam guiding and forming
- Marking
- Removal and drilling
- Change material properties
- Cutting including process control
- Welding of metals including process control
- Hybrid welding processes
- Welding of nonmetals
- Bonding / soldering- Additive manufacturing

Vorkenntnisse

Basic optics, basics of laser sources recommended

Literatur

Recommendation is given in the lecture; Lecture notes

Besonderheit

Lectures and exercises in the rooms of the Laser Zentrum Hannover e.V. (laboratories / experimental field). Lecture und examination are offered in English and German. The course's name on Stud.IP is "Lasermaterialbearbeitung"

Modulname	Laser Measurement Technology		
Modulname EN	Laser Measurement Technology		
Verantw. Dozent/-in	Roth	Semester	SoSe
Institut	Hannoversches Zentrum für Optische Technologien	ECTS	5
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schriftlich
Präsenzstudienzeit	40	Selbststudienzeit	110
	Kursumfang	V2/U1	

Modulbeschreibung

The aim of this lecture course is the introduction to the basic principles and methods of state-of-the-art optical measurement technology based on laser sources. An overview of the broad spectrum of laser sources, measurement techniques, and typical practical applications for various optical measurement, monitoring, and sensing situations in research and development will be provided. The exercise course aims at consolidating the understanding of the basic principles and provides theoretical exercises according to selected example applications and practical laboratory training.

Content:

- Basic physics
- Optical elements/detection techniques
- Lasers for measurement applications
- Laser triangulation and interferometry
- Distance and velocity measurement

Vorkenntnisse

Fundamentals of measurement technology, Basics of laser physics and laser technology

Literatur

A. Donges, R. Noll, Lasermesstechnik, Hüthig Verl.; M. Hugenschmidt, Lasermesstechnik, Springer Verl.; W. Lange, Einführung in die Laserphysik, Wissenschaftliche Buchgesellschaft, Darmstadt; Bei vielen Titeln des Springer-Verlages gibt es im W-Lan der LUH unter www.springer.com eine Gratis Online-Version.

Besonderheit

Recommended for second semester and higher (Master course)

Modulname	Laserinterferometrie		
Modulname EN	Laser Interferometry		
Verantw. Dozent/-in	Heinzel	Semester	WiSe
Institut	Institut für Gravitationsphysik	ECTS	2
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schrift./münd.
Präsenzstudienzeit	32	Selbststudienzeit	28
		Kursumfang	V2

Modulbeschreibung

Students acquire knowledge of modern laser interferometry. The emphasis of the lecture is laid in laser interferometers for gravitational wave detection such as well as in laser interferometry on satellites (LISA Pathfinder, GRACE Follow-On, LISA).

Contents:

- Michelson-, Mach-Zehnder- und Fabry-Perot interferometer
- Thermal noise
- Mechanical quality of hanging lenses
- Applications for measurement of Gravitational waves and the gravity field of the earth
- Description Gaussian rays and higher methods
- Transformation of Gaussian rays
- Selection procedures: Internal, external and Schnup modulation; Pound-Drever Hall procedure
- Polarization
- Transfer function and control loops

Applications: GEO600, LISA, GRACE Follow-On

Vorkenntnisse

Coherent Optics, nonlinear Optics

Literatur

Saulson: Fundamentals of Interferometric Gravitational Wave Detectors, World Scientific, 1994; Amnon Yariv: Quantum Electronics; Siegman: Lasers

Besonderheit

Modulname	Laserscanning - Modelling and Interpretation		
Modulname EN	Laserscanning - Modelling and Interpretation		
Verantw. Dozent/-in	Brenner	Semester	WiSe
Institut	Institut für Kartographie und Geoinformatik	ECTS	5
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	mündlich
Präsenzstudienzeit	40	Selbststudienzeit	110
		Kursumfang	V2/U1

Modulbeschreibung

Aim of the module: This lecture imparts the basic principles about laser scanning and its respective application areas.

After successful completion of the lecture, students are able to explain and apply selected techniques and algorithms for the low-, intermediate- and high-level processing of laser scanning data.

Lecture content: Airborne, terrestrial and mobile mapping laser scanning: scan geometry and technical characteristics. Low-, intermediate and high-level tasks. Representation of 3D rotations: matrix, angles, axis and angle, quaternions. Estimation of similarity transforms and the iterative closest point algorithm. Estimation and segmentation of lines and planes. Region growing, RANSAC and MSAC, Hough transform, scanline grouping. Scanning and segmentation in robotics applications. Decision trees and random forests for point cloud classification. Markov chains and Markov chain Monte Carlo methods and their use for high-level interpretation. In the exercises, selected algorithms will be programmed.

Vorkenntnisse

Programmierkenntnisse

Literatur

Skript

Besonderheit

Lecture is given in English

Modulname	Laserspektroskopie in Life Science		
Modulname EN	Laser Spectroscopy in Life Sciences		
Verantw. Dozent/-in	Roth	Semester	WiSe
Institut	Hannoversches Zentrum für Optische Technologien	ECTS	5
Art	<input checked="" type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schriftlich
Präsenzstudienzeit	32	Selbststudienzeit	88
		Kursumfang	V2/U1

Modulbeschreibung

The aim of this lecture course is the introduction to the fundamentals and methods in laser spectroscopy for application in the life sciences. Apart from the basic principles of laser spectroscopic techniques and methods applied in various up-to-date areas of fundamental research also practical applications in the life sciences such as biology, chemistry, and medicine, will be taught. The students will also gain insight into modern measurement devices and methods which are broadly employed. The exercise course aims at consolidating the understanding of the basic principles given as well as at their application for practical examples.

Vorkenntnisse

Mandatory: Basic physics, optics and laser physics, laser applications Recommended: optical components and measurement principles, spectroscopy, laser interferometry, (ultra) short pulse laser

Literatur

Wolfgang Demtröder: Laserspektroskopie 1: Grundlagen (Springer), 2011 Wolfgang Demtröder: Laserspektroskopie 2: Experimentelle Techniken (Springer), 2012 Jürgen Eichler, Hans Joachim Eichler: Laser - Bauformen Strahlführung Anwendungen (Springer), 2006: Bei vielen Titeln des Springer-Verlages gibt es im W-Lan der LUH unter www.springer.com eine Gratis Online-Version.

Besonderheit

Recommended for second semester and higher (Master course).

Modulname	Nichtlineare Optik		
Modulname EN	Non-linear Optics		
Verantw. Dozent/-in	Morgner	Semester	SoSe
Institut	Institut für Quantenoptik	ECTS	5
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schrift./münd.
Präsenzstudienzeit	42	Selbststudienzeit	108
		Kursumfang	V3/U1

Modulbeschreibung

The students acquire special knowledge of nonlinear laser optics and can apply the necessary mathematical methods themselves.

- Nonlinear optical susceptibility
- Crystal optics, tensor optics
- Wave equation with nonlinear source terms
- Frequency doubling, sum-, difference-frequency generation
- Optical parametric amplifier, oscillator
- Phase-matching schemes, quasi phase-matching
- Electro-optical effect
- Electro-acoustic modulator
- Frequency tripling, Kerr-effect, self-phase modulation, self-focusing
- Raman-, Brillouin-scattering, four wave mixing
- Nonlinear propagation, solitons

Vorkenntnisse

Physik II, Experimentalphysik, Atom- und Molekülphysik / Physics II, Experimental Physics, Atomic and Molecular Physics

Literatur

Agrawal: Nonlinear Fiber optics, Academic Press; Boyd: Nonlinear Optics, Academic Press; Shen: Nonlinear Optics; Dmitriev: Handbook of nonlinear crystals, Springer;

Besonderheit

The course's name on Stud.IP is "Nichtlineare Optik"

Modulname	Oberstufenlabor: Dämpfung in Lichtwellenleitern		
Modulname EN	MasterLab: Attenuation in optical fibers		
Verantw. Dozent/-in	Schrein	Semester	WiSe
Institut	Institut für Transport- und Automatisierungstechnik	ECTS	1
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung		Prüfungsform	Labor
Präsenzstudienzeit	15	Selbststudienzeit	15
		Kursumfang	L1

Modulbeschreibung

In this lab course, the optical attenuation of optical fibers is investigated. Three LEDs with different wavelengths are used. The LEDs are first characterized electrically and optically and then coupled into the light waveguides. By measuring the optical power before and after the waveguide, the wavelength dependence of the optical attenuation can be demonstrated.

Vorkenntnisse

Literatur

Besonderheit

When registering, please note that groups with less than 4 participants may be split between other dates. The lab course is located in the ITA in Garbsen and is led by Daniel Schrein (daniel.schrein@ita.uni-hannover.de). On lab day, we will meet in the foyer of the institute.

Modulname	Oberstufenlabor: Emissionsspektren		
Modulname EN	MasterLab: Emission Spectra		
Verantw. Dozent/-in	Weber	Semester	WiSe
Institut	Institut für Quantenoptik	ECTS	1
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung		Prüfungsform	Labor
Präsenzstudienzeit	15	Selbststudienzeit	15
		Kursumfang	L1

Modulbeschreibung

In this experiment you will use a diffraction grating within a goniometer setup to analyse the spectra of different light sources. Thereby the concept of interference is central. Moreover you will determine the resolution power of the diffraction grating by analysis of the Sodium D-lines. It is necessary to prepare the content for the experiment. Your preparation will be tested with an assessment during the Lab.

The Lab is located in room 143A of building 1105. If you have further questions regarding the experiment, please contact Kim Weber (weber@iqo.uni-hannover.de).

Vorkenntnisse

Literatur

Besonderheit

Modulname	Oberstufenlabor: Michelson Interferometer		
Modulname EN	MasterLab: Michelson Interferometer		
Verantw. Dozent/-in	Weber	Semester	WiSe
Institut	Institut für Quantenoptik	ECTS	1
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung		Prüfungsform	Labor
Präsenzstudienzeit	15	Selbststudienzeit	15
		Kursumfang	L1

Modulbeschreibung

The Michelson interferometer is a basic configuration for optical interferometry. The experiment enables you to study interference phenomena. The aim of the lab course is to develop an elaborate and sustainable concept of coherence. You will utilize the experimental setup as a precise apparatus to measure differences in optical path length. Moreover you will train your skills in adjusting of optical components. It is necessary to prepare the content for the experiment. Your preparation will be tested with an assessment during the Lab.

The Lab is located in room -141 of building 1105. If you have further questions regarding the experiment, please contact Kim Weber (weber@iqo.uni-hannover.de).

Vorkenntnisse

Literatur

Besonderheit

Modulname	Oberstufenlabor: Speckle Interferometer			
Modulname EN	MasterLab: Speckle Interferometer			
Verantw. Dozent/-in	Suar		Semester	WiSe
Institut	Hannoversches Zentrum für Optische Technologien		ECTS	1
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien			
Vertiefungsrichtung			Prüfungsform	Labor
Präsenzstudienzeit	15	Selbststudienzeit	15	Kursumfang
				L1

Modulbeschreibung

Electronic Speckle Pattern Interferometry (ESPI) is a laser based optical technique which enables the full-field measurement of small deformations of object surfaces with sub-wavelength accuracy. ESPI is successfully applied to many other fields, e.g. automotive, aerospace, electronics and materials research. In this experiment, a rough surface is illuminated with coherent laser light and the subsequent imaging is observed by using a CCD camera which generates the statistical interference patterns, the so-called speckles. A reference light is also generated by the split out from the original laser source and then superimposed with the speckles from object beam to result in an interferogram. The speckle interferogram also changes when the object under test is deformed by mechanical means. Comparing the interferogram of the surface before and after mechanical loading will result on a fringe pattern which reveals the displacement of the surface during loading as contour lines of deformation. The details about the lab experiment is provided in the problem sheet.

The master lab is carried out at the HOT (Hannoversches Zentrum für Optische Technologien). You will be picked up at the institute entrance by the respective supervisors and taken to the laboratory. If you have further questions regarding the experiment, please send an e-mail to Monali Suar (monali.suar@hot.uni-hannover.de).

Vorkenntnisse

Literatur

Besonderheit

Modulname	Oberstufenlabor: Videoprojektortertechnologie		
Modulname EN	MasterLab: Video Project Technology		
Verantw. Dozent/-in	Leuteritz	Semester	WiSe
Institut	Institut für Produktentwicklung und Gerätebau	ECTS	1
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung		Prüfungsform	Labor
Präsenzstudienzeit	15	Selbststudienzeit	15
		Kursumfang	L1

Modulbeschreibung

Optical technologies are regarded as one of the key technologies of the 21st century and are used, among other things, for the processing of materials, sensor technology, data transmission, the projection of information and lighting technology. Since humans obtain about 90 % of the information perceived from their environment from the visual, optical technologies provide a powerful interface in human-machine communication. One challenge here is to reproduce information optically. It must therefore be investigated which influencing variables of the optical systems can be used for targeted information transmission. Here, the influences of the human eye have to be considered.

A technical implementation of information transmission is represented by video projectors, which specifically generate light distributions on different surfaces. In particular, the requirements to reproduce a large colour spectrum and to achieve high contrast values are decisive for the quality of the projection.

In the IPeG's optomechanics experiment, the functionality of video projectors is investigated. The focus of the experiment is on the interaction of colour generation and human colour perception. Technical possibilities are discussed to realize defined colour spaces and colour impressions. The influences of the human eye and the resulting technical challenges are highlighted.

The MasterLab is carried out at the Institute of Product Development (Building 1105). You will be picked up at the institute entrance by the respective supervisors and taken to the laboratory. Please keep yourself up to date regarding changes of dates via Stud.IP, as it is possible that the lab days will be postponed due to the Garbsen move. If you have further questions regarding the experiment, please send an e-mail to Georg Leuteritz (leuteritz@ipeg.uni-hannover.de).

Vorkenntnisse

Literatur

Besonderheit

Modulname	Optical properties of Micro- and Nanostructures				
Modulname EN	Optical properties of Micro- and Nanostructures				
Verantw. Dozent/-in	Cala Lesina			Semester	WiSe
Institut	Hannoversches Zentrum für Optische Technologien			ECTS	5
Art	<input type="checkbox"/> Pflicht <input checked="" type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien				
Vertiefungsrichtung				Prüfungsform	schrift./münd.
Präsenzstudienzeit	52	Selbststudienzeit	98	Kursumfang	V2/U2

Modulbeschreibung

Optical devices based on micro- and nanostructures are progressively replacing conventional optical systems (such as bulky lenses) due to their small dimensions and ease of integration. This course provides the basic knowledge of micro- and nano-optics (or nanophotonics) to understand and design such miniaturized optical systems, as well as examples of their applications.

After successfully completing the module, students are able to
(Qualification goals)

- Understand Maxwell's equations and describe light propagation.
- Understand the optical properties of matter and the interaction of light with matter.
- Know the main categories of micro- and nano-structures and describe their optical properties.
- Simulate a simple micro- or nanostructured system and understand its optical properties.

Module content

- Maxwell's equation, wave equation, reflection and refraction.
- Optical properties of metals and dielectrics, fundamentals of plasmonics.
- Metasurfaces, photonic crystals, diffraction gratings, micro-lenses, nano-films.
- Lab activity on how to use optical simulation software.

Vorkenntnisse

Mathematics and Physics (First year courses)

Literatur

Fundamentals of photonics, B.E.A. Saleh, M.C. Teich, Wiley, 2019.

Besonderheit

Modulname	Optik, Atomphysik und Quantenphänomene		
Modulname EN	Optics, Nuclear Physics und Quantum Phenomena		
Verantw. Dozent/-in	Heisterkamp	Semester	WiSe
Institut	Institut für Quantenoptik	ECTS	8
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schriftlich
Präsenzstudienzeit	64	Selbststudienzeit	176
		Kursumfang	V3/U1/L3

Modulbeschreibung

Geometrische Optik, Welleneigenschaften des Lichts: Interferenz, Beugung, Polarisation, Doppelbrechung, Optik, optische Instrumente, Materiewellen, Welle-Teilchen-Dualismus, Aufbau von Atomen, Energiezustände, Drehimpuls, magnetisches Moment, Mehrelektronensysteme, Pauli-Prinzip, Spektroskopie, spontane und stimulierte Emission, Praktikumsexperimente (Linsen, Interferometer, Beugung, Mikroskop, Prisma, Gitter, Fotoeffekt, Spektralapparat, Polarisation)

Vorkenntnisse

keine

Literatur

Demtröder: "Experimentalphysik 2 und 3"; Springer Verlag; Berkeley Physikkurs; Bergmann/Schäfer; Haken, Wolf: "Atom- und Quantenphysik".

Besonderheit

keine

Modulname	Optische 3D Messtechnik				
Modulname EN	Optical 3D Measurements				
Verantw. Dozent/-in	Wiggenhagen			Semester	SoSe
Institut	Institut für Photogrammetrie und Geoinformation			ECTS	5
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien				
Vertiefungsrichtung	Optional Modules			Prüfungsform	mündlich
Präsenzstudienzeit	48	Selbststudienzeit	102	Kursumfang	V2/U2

Modulbeschreibung

As part of this lecture, students acquire knowledge in optical 3D metrology using digital cameras. The focus is on the stereoscopic recording and evaluation in indoor and outdoor projects with the aim of being able to calculate both highly accurate and statistically reliable three-dimensional point coordinates from multiple images and adapted estimation methods and to generate surfaces. The students get to know the advantages and disadvantages of different sensors (commonly available cameras, special measuring cameras, systems with active lighting) and learn to calibrate them accordingly. Current practical applications supplement the theoretical material.

Vorkenntnisse

Successful participation in the lecture "Photogrammetric Computer Vision"

Literatur

T. Luhmann, Nahbereichsphotogrammetrie, Wichmann Verlag, ISBN 978-3-87907-479-2 Klette, Koschan, Schlüns, Computer Vision, Räumliche Information aus digitalen Bildern, Verlag Vieweg & Teubner, ISBN 978-3-528-06625-3

Besonderheit

Exercises take place during the lecture using modern imaging sensors. The course's name on Stud.IP is "Optische 3D Messtechnik"

Modulname	Optische Messtechnik				
Modulname EN	Optical Measuring Technology				
Verantw. Dozent/-in	Rahlves			Semester	WiSe
Institut	Hannoversches Zentrum für Optische Technologien			ECTS	5
Art	<input checked="" type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien				
Vertiefungsrichtung				Prüfungsform	schrift./münd.
Präsenzstudienzeit	58	Selbststudienzeit	92	Kursumfang	V2/U2

Modulbeschreibung

The lecture gives an overview on theory, methods and devices in optical metrology. At the beginning, fundamentals of optics and photonics such as ray and wave optics are revised, which are essential for the understanding of concepts in optical metrology. Focusing on metrology in research and industrial applications, the lecture covers optical methods for measurement of topography, distance, and deformation as well as fiber optical sensors, which include concepts such as interferometry, holography and confocal microscopy. In addition, semi-optical methods such as atomic force microscopy and near field microscopy are addressed and compared to non-optical methods, e.g., scanning electron microscopy. To gain an in-depth understanding of the concepts involved in optical metrology, all devices and optical setups are explained in detail including light sources, cameras, and optical elements.

Vorkenntnisse

Messtechnik I / Measurement Technology I

Literatur

Born, Wolf: Principles of Optics: Electromagnetic Theory of Propagation, Interference and Diffraction of Light; Demtröder: Experimentalphysik; Saleh, Teich: Grundlagen der Photonik; Lauterborn, Kurz: Coherent Optics; Goodman: Introduction to Fourier Optics; Hugenschmidt: Lasermesstechnik; Bei vielen Titeln des Springer-Verlages gibt es im W-Lan der LUH unter www.springer.com eine Gratis Online-Version.

Besonderheit

Prüfung je nach Teilnehmerzahl: Einzelprüfung mündlich 20 Min. oder schriftlich 90 Min.

Modulname	Optische Radiometrie		
Modulname EN	Optical Radiometry		
Verantw. Dozent/-in	Kovacev	Semester	SoSe
Institut	Institut für Quantenoptik	ECTS	-
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schrift./münd.
Präsenzstudienzeit	24	Selbststudienzeit	Kursumfang V2

Modulbeschreibung

Contents:

- Radiometry
- Photometry
- Optical devices for light measurement
- Laser safety

Example projects:

Build up of a Power-Meter, Spectroscopy, Radiometry measurements of hazardous light sources, Light pulse detection, Coherent diffraction imaging, UV microscopy

Vorkenntnisse

Literatur

Besonderheit

A new teaching concept will give the students the possibility to build their knowledge from hands-on projects. This concept aims to provide training for students in basic research skills like presenting, evaluating and analysing experimental research.

Modulname	Optische Schichten				
Modulname EN	Optical Coatings and Layers				
Verantw. Dozent/-in	Ristau			Semester	WiSe
Institut	Laser Zentrum Hannover e.V.			ECTS	4+1
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien				
Vertiefungsrichtung	Optional Modules			Prüfungsform	schrift./münd.
Präsenzstudienzeit	50	Selbststudienzeit	100	Kursumfang	V2/U2/P1

Modulbeschreibung

Optical coatings can be considered as essential key-components in modern Photonics. For example, present laser sources, optical systems and products or even a major part of fundamental research could never be realized without optical coatings. In the course the fundamentals of coating design, production and characterization of functional layer systems will be presented.

Recent research areas of optical coating technology, especially in the fields of high precision industrial production and the optimization of coating systems for high power lasers will be introduced and discussed. The course offers a large variety of practical information on optical coatings, which may be of value for engineers and physicists heading towards a career in photonics.

Contents:

- General basis (applications, impact, and functional principle of optical coatings, state of the art in coatings for laser technology)
- Theoretical fundamentals (compilation of formulae and consideration of fundamental phenomena, calculation of single layers and layer systems)
- Production of optical components (substrates, coating materials and techniques, control of coating processes)
- Optics characterization (measurement of optical transfer properties, optical losses: Total Scattering and absorption, laser induced damage thresholds of laser components, non-optical properties)

Vorkenntnisse

Fundamentals of optics and physics.

Literatur

Will be announced during the course, for an introduction: Macleod, H.A.: Thin Film Optical Filters, Fourth Edition, CRC Press 2010

Besonderheit

Three exercise sheets for homework, solution of exercises discussed during the course, major course assessment alternatively by colloquium, oral examination, or by written test Compulsory internship (1 CP) with a duration of approx. 16 hours. The internship can only be completed after successful completion of the examination. The internship includes a general introduction to technological aspects of optical thin-film production taking about 4 hours and a technical part. The technical part will usually be directed to the production of an exemplary layer system and its analysis. The internship can be completed in three short blocks of 4 hours each at the LZH. The course's name on Stud.IP is "Optische 3D Messtechnik"

Modulname	Photogrammetric Computer Vision				
Modulname EN	Photogrammetric Computer Vision				
Verantw. Dozent/-in	Heipke		Semester	WiSe	
Institut	Institut für Photogrammetrie und Geoinformation		ECTS	5	
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien				
Vertiefungsrichtung	Optional Modules		Prüfungsform	mündlich	
Präsenzstudienzeit	32	Selbststudienzeit	120	Kursumfang	V2/U2

Modulbeschreibung

Lecture content

Short introduction into aims, commonalities and differences of photogrammetry and computer vision, 3D image processing, projective geometry: transformation between image and object space, in linear models. Robust estimation (RANSAC). Different methods to represent 3D rotations (Euler angles axis-angle representation, quaternions). Structure from motion (sfm) from stereoscopic images and image sequences: interest operators (SIFT, SURF), sliding pose estimation, dense image matching, determination of object geometries. Methods for evaluation of results of image based approaches.

Aims of the lecture

After studying the module the students have a good overview and detailed knowledge of some exemplary methods of 3D reconstruction from images and image sequences (structure from motion, sfm). They understand the geometric transformations between image and object space, the usual procedures for pose estimation of moving sensors and basics of signal theory as applied to image matching. Students can thus evaluate pros and cons of sfm.

In the lab part, carried out in small groups, image sequences are captured using flying robots; these image sequences are being exploited using available software. In this way the students come to gain practical experience of digital image capture and geometric 3D reconstruction and can evaluate the obtained results.

Vorkenntnisse

Bachelorabschluss in einem Ingenieurfach.

Literatur

David A. Forsyth and Jean Ponce (2003). Computer Vision, A Modern Approach. Prentice Hall. Richard Hartley and Andrew Zisserman (2003). Multiple View Geometry in Computer Vision. Cambridge University Press. Richard Szeliski (2010): Computer Vision, Springer, London, szeliski.org/Book/, see also www.eecs.berkeley.edu/~trevor/CS280.html <http://www.cs.cmu.edu/~cil/vision.html>

Besonderheit

This lecture is given in English

Modulname	Photonics		
Modulname EN	Photonics		
Verantw. Dozent/-in	Dozenten der Quantenoptik	Semester	WiSe
Institut	Institut für Quantenoptik	ECTS	5
Art	<input checked="" type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung		Prüfungsform	schrift./münd.
Präsenzstudienzeit	60	Selbststudienzeit	90
		Kursumfang	L2/E1

Modulbeschreibung

The students gain special knowledge in nonlinear and integrated optics, and they can apply the corresponding mathematical methods. A special topic of photonics can be selected and deepened independently by the student. The topic shall be presented in the frame of a seminar with a subsequent discussion. Besides their technical competence, the students develop their methods in literature research, implementation of technical and scientific knowledge, as well as their presentation techniques together with their ability to lead scientific discussions.

Contents:

- Waves in Media and at Boundaries
- Dielectric Waveguides (planar, fiber), Integrated Waveguides
- Waveguide Modes
- Nonlinear Fiber Optics
- Fiber optic components (Circulators, AWG, Fiber-Bragg-Gratings, Modulators), Optical Communication (WDM/TDM)
- Fiberlaser
- Laserdiodes, Photodetectors
- Plasmonics, Photonic Crystals
- Transformation Optics

Vorkenntnisse

Basic knowledge in coherent optics, Nonlinear Optics Lecture

Literatur

Saleh, Teich: Photonics, Wiley; Maier: Plasmonics: Fundamentals and Applications, Springer; Boyd: Nonlinear Optics, Academic Press

Besonderheit

Final mark: 80% oral exam, 20% seminar.

Modulname	Production of Optoelectronic Systems				
Modulname EN	Production of Optoelectronic Systems				
Verantw. Dozent/-in	Overmeyer			Semester	WiSe
Institut	Institut für Transport- und Automatisierungstechnik			ECTS	5
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien				
Vertiefungsrichtung	Optional Modules			Prüfungsform	schriftlich
Präsenzstudienzeit	40	Selbststudienzeit	110	Kursumfang	L2/E2

Modulbeschreibung

Outcomes: This module gives basic knowledge about processes and devices that are used in production of semiconductor packages and microsystems. The main focus is on the back-end-process that means the process thins wafer dicing. After successful examination in this module the students are able to

- correctly use the terms optoelectronic system, wafer production, front end and back end and to give an overview of production processes of semiconductor packages
- explain the production processes beginning from crude material sand and to have an idea about process relevant parameters
- visualize different packaging techniques and explain the corresponding basics of physics
- choose and classify different package types for an application

Contents:

- Wafer production
- Mechanical Wafer treatment
- Mechanical connection methods (micro bonding, soldering, eutectic bonding)
- Electrical connection methods (wire bonding, flip chip bonding, TAB)
- Package types for semiconductors
- Testing and marking of packages
- Design and production of printed circuit boards
- Printed circuit board assembly and soldering techniques

Vorkenntnisse

Literatur

Lau, John H.: Low cost flip chip technologies : for DCA, WLCSP, and PBGA assemblies. McGraw-Hill, New York 2000. Pecht, Michael: Integrated circuit, hybrid, and multichip module package design guidelines : a focus on reliability. Wiley, New York 1994. Bei vielen Titeln des Springer-Verlages gibt es im W-Lan der LUH unter www.springer.com eine Gratis Online-Version.

Besonderheit

Modulname	Proseminar Biophotonik		
Modulname EN	Proseminar Biophotonics		
Verantw. Dozent/-in	Dozenten der Quantenoptik, Morgner	Semester	Wi-/SoSe
Institut	Hannoversches Zentrum für Optische Technologien	ECTS	3
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	Seminar
Präsenzstudienzeit	30	Selbststudienzeit	60
		Kursumfang	V2

Modulbeschreibung

The focus of the proseminar lies on the applications of optical technologies, methods and processes in the life sciences. The students acquire knowledge on both basic concepts and their implementation into real applications. Typical fields of application are optical microscopy and imaging for medical diagnosis or precision laser spectroscopy for the investigation of the functionality of biomolecules and molecular analytics. Furthermore, emphasis will be placed on modern optical technology for lab-on-chip applications and integrated laser methods for medical screening, among others.

Vorkenntnisse

Basics of physics, Optical elements / Measurement techniques, Physical foundations of optics and laser technology, Basic knowledge in laser applications

Literatur

Besonderheit

Graded performance: oral examination and presentation slides Type of examination: oral (marked or unmarked, as required) The course's name on Stud.IP is "Proseminar Grundlagen der Biophotonik"

Modulname	Radar Remote Sensing		
Modulname EN	Radar Remote Sensing		
Verantw. Dozent/-in	Motagh	Semester	WiSe
Institut	Institut für Photogrammetrie und Geoinformation	ECTS	3
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	mündlich
Präsenzstudienzeit	30	Selbststudienzeit	60
		Kursumfang	2V/U1

Modulbeschreibung

Lecture content

- Introduction to two-dimensional radar imaging and Synthetic Aperture Radar (SAR)
 - Geometric and physical properties of SAR images
 - SAR interferometry to measure Earth's surface topography and deformation
 - Fundamental equation of Interferometry:
 - Interferometric phase quality: Coherence, Phase Unwrapping, error spurces
- Lab: lab assignments in Operational Remote Sensing and in Radar Remote Sensing.
- Optional excursions will be offered to DLR Oberpfaffenhofen and to GFZ Potsdam, both towards the end of the semester.

Goals

In this this course, students shall gain an understanding for the technique of radar remote sensing with an emphasis on Synthetic Aperture Radar (SAR), Interferometry Synthetic Aperture Radar (InSAR), and multi-temporal interferometry (MTI) techniques and their applicability to various types of natural disasters and engineering tasks.

Vorkenntnisse

Some familiarity with a Linux operating system is beneficial for lab exercises

Literatur

Massonnet, D., & Feigl, K. L. (1998). Radar interferometry and its application to changes in the earth's surface. *Reviews of Geophysics*, 36, 441-500.

Besonderheit

This lecture will be given in English.

Modulname	Remote Sensing I		
Modulname EN	Remote Sensing I		
Verantw. Dozent/-in	Melsheimer	Semester	WiSe
Institut	Institut für Meteorologie und Klimatologie	ECTS	4
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	mündlich
Präsenzstudienzeit	32	Selbststudienzeit	88
		Kursumfang	V2/U1

Modulbeschreibung

Overview:Overview:

- Fundamentals for measurements from satellites and their application for the acquisition of atmospheric processes
- Remote sensing methods using satellite instruments. Derivation of temperature, cloud and trace gas measurements with remote sensing instruments from satellite and ground.
- Derivation of radiation measurements from satellite data

Vorkenntnisse

Mandatory: Remote Sensing I, Radiation I, Recommended: Radiation II, Introduction to Meteorology

Literatur

Kidder, S. Q.; Vonder Haar, T.H.: Satellite Meteorology: An Introduction, Academic Press, San Diego 1995.

Besonderheit

The course's name on Stud.IP is "Fernerkundung I"

Modulname	Remote Sensing II		
Modulname EN	Remote Sensing II		
Verantw. Dozent/-in	Melsheimer	Semester	WiSe
Institut	Institut für Meteorologie und Klimatologie	ECTS	4
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	mündlich
Präsenzstudienzeit	32	Selbststudienzeit	88
	Kursumfang	V2/U1	

Modulbeschreibung

Qualification Goal

The Students deepen their basic knowledge about remote sensing (cf. lecture Remote Sensing I), beyond the domain of meteorology - area of application are now the geosciences in a broad sense. They are enabled to efficiently make use of remote sensing (satellite-based, ground-based or on other platforms) in scientific problems in the geosciences.

Contents:

Basics about measurements with remote sensing instruments (at the ground, on satellites, on other platforms), using visible and infrared light and microwaves:

- Electromagnetic radiation, its generation and measurement;
- radiative transfer;
- important methods and instruments for remote sensing of (1) solid earth surface (e.g., monitoring of vegetation, surface temperature) (2) the oceans (e.g., determining primary production, wind, sea state) (3) the atmosphere (e.g., trace gas measurement, determining the temperature profile)

Vorkenntnisse

Mandatory: Remote Sensing I, Radiation I, Recommended: Radiation II, Introduction to Meteorology

Literatur

Kidder, S. O.; Vonder Haar, T.H.: Satellite Meteorology: An Introduction, Academic Press, San Diego 1995.

Besonderheit

The course's name on Stud.IP is "Fernerkundung II"

Modulname	Seminar Numerischer Optik		
Modulname EN	Seminar Numerical Optics		
Verantw. Dozent/-in	Demircan	Semester	SoSe
Institut	Institut für Quantenoptik	ECTS	3
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	Seminar
Präsenzstudienzeit	32	Selbststudienzeit	58
	Kursumfang	S2	

Modulbeschreibung

Seminar covering selected topics for the calculation of light distributions in optical media

Contents:

- Spectral- and pseudospectral methods
- Runge-Kutta- and Split-Step-Integration
- Fast-Fourier Transform (FFT)
- Monte Carlo (MC) simulation
- Finite Difference Time Domain (FDTD)
- Finite Element Methods
- Ray Tracing
- Beam-propagation methods (BPM)
- Parallelization using MPI

Vorkenntnisse

Literatur

Besonderheit

Modulname	Seminar Optics at Femto- and Attoscond Scales		
Modulname EN	Seminar Optics at Femto- and Attoscond Scales		
Verantw. Dozent/-in	Morgner, Kovacev	Semester	Wi-/SoSe
Institut	Institut für Quantenoptik	ECTS	3
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	Seminar
Präsenzstudienzeit	32	Selbststudienzeit	58
		Kursumfang	S2
Modulbeschreibung			
Hochleistungs-Femtosekunden-Lasersysteme Wechselwirkung von Materie mit starken Feldern Filamentation/Plasmakanäle Die absolute Trägerphase Quanten-Interferenz-Metrologie /Modenkämme Relativistische Optik / Laser-Teilchenbeschleunigung Erzeugung und Nachweis hoher Harmonischer Erzeugung und Nachweis von Attosekunden-Pulsen Atomare Fotografie Der Freie-Elektronen-Laser			
Vorkenntnisse			
Literatur			
Besonderheit			
Für optische Technologien. The course's name on Stud.IP is "Seminar Optik auf Femto- und Attosekunden-Zeitskalen"			

Modulname	Seminar Theorie und Praxis optischer Funktionsschichten				
Modulname EN	Seminar Theory and practice of optical functional layers				
Verantw. Dozent/-in	Ristau		Semester	SoSe	
Institut	Institut für Quantenoptik		ECTS	3	
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien				
Vertiefungsrichtung	Optional Modules		Prüfungsform	Seminar	
Präsenzstudienzeit	28	Selbststudienzeit	62	Kursumfang	S2

Modulbeschreibung

The major objective of the seminar is to acquire advanced skills concerning the characterization, calculation, and simulation of optical functional layers. After an introduction by the lecturers, defined tasks shall be studied in small groups (up to 3 persons, also of varying composition, all groups work in parallel on one issue, also for several days according to the specific task). The results obtained by the groups for the tasks will be briefly presented in a synopsis and jointly evaluated. The corresponding tasks include practical as well as theoretical aspects, however calculations and simulations will be in the foreground of the studies. The necessary equipment will be available at the Laser Zentrum Hannover. Work on own computers will be also possible and supported by granting the necessary software packages (licenses with limited usage time). The following tasks can be considered as a preliminary selection addressed by the seminar:

- theoretical foundations: thin-film technology
- introduction to the thin film software
- internship: (preparation and characterization of a single-layer)
- **determination of optical parameters by means of the "Spektrum Software"**
- anti-reflective coatings and highly reflective mirror calculated with thin film software
- complex systems: broad band mirrors and broadband anti-reflective coatings
- complex systems: Mirrors with defined phase gradients and/or Rugate structures
- considerations on layer simulation
- atomistic

Vorkenntnisse

Lecture "Optical coatings"

Literatur

Besonderheit

The course's name on Stud.IP is "Seminar Theorie und Praxis optischer Funktionsschichten"

Modulname	Solid State Lasers		
Modulname EN	Solid State Lasers		
Verantw. Dozent/-in	Weßels	Semester	SoSe
Institut	Laser Zentrum Hannover e.V.	ECTS	2
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	mündlich
Präsenzstudienzeit	32	Selbststudienzeit	28
	Kursumfang	L2	

Modulbeschreibung

Within this lecture the fundamentals needed for the understanding of modern solid state lasers will be developed. In particular, the optical properties and typical parameters of different solid state laser designs will be developed. Furthermore, the application potential of the various solid laser designs will be treated.

Contents:

- Solid state laser media
- optical resonators
- laser modes of operation
- diode pumped solid state lasers
- laser designs: fiber, rod, disc; tunable lasers
- single-frequency lasers
- ultrashort-pulse lasers
- frequency conversion

Vorkenntnisse

Basic knowledge in physics and coherent optics.

Literatur

W. Koehler, Solid-State Laser Engineering A. E. Siegman, Lasers; O. Svelto, Principles of Lasers.

Besonderheit

This course is equivalent to the german taught module "Fundamentals and Configuration of Laser Beam Sources". Only one of these modules may be credited for the master course, respectively.

Modulname	Spray Technology		
Modulname EN	Spray Technology		
Verantw. Dozent/-in	Kawaharada	Semester	WiSe
Institut	Institut für Technische Verbrennung	ECTS	3
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schrift./münd.
Präsenzstudienzeit	30	Selbststudienzeit	60
		Kursumfang	V2

Modulbeschreibung

This course conveys fundamentals of spray technology and its applications. After successfully completing the course, students will be able to

- explain and differentiate spray processes in detail including characteristic numbers,
- sketch experimental and numerical approaches to spray investigations,
- explain typical examples of applications for various sprays and atomizers.

Content:

- Fundamentals and types of sprays
- Atomizers and injectors
- Measurements techniques
- Spray modeling
- Applications
- Lab exercises

Vorkenntnisse

Needed: Basics of fluid mechanics; Wanted: Multiphaseflows, Verbrennungstechnik

Literatur

Lefebvre, Arthur: Atomization and Sprays

Besonderheit

keine

Modulname	Studienarbeit		
Modulname EN	Project Work		
Verantw. Dozent/-in	Diverse Institute Maschinenbau	Semester	Wi-/SoSe
Institut	Diverse	ECTS	10
Art	<input checked="" type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung		Prüfungsform	schrift./münd.
Präsenzstudienzeit		Selbststudienzeit	
		Kursumfang	300h

Modulbeschreibung

Mit der Studienarbeit schärfen Studierende ihre wissenschaftliche Arbeitsweise und -kompetenz und arbeiten selbständig an einem wissenschaftlichen Thema unter Betreuung eines der am Studiengang beteiligten Institute. Neben der Herausarbeitung einer wissenschaftlichen Fragestellung gibt die Studienarbeit Platz geeignete wissenschaftliche Methoden auszuwählen, um in Test- und Laborreihen zu wissenschaftlichen Ergebnissen zu erlangen, die es zu hinterfragen gilt. Die Ergebnisse der Studienarbeit werden zudem vor dem Betreuungspersonal präsentiert und dargelegt. Die Studienarbeit bereitet auf die sich anschließende Masterarbeit vor. Ihr Workload beläuft sich auf 300 Stunden.

Students sharpen their scientific skills and their scientific Mode of operation and work independently on a scientific topic under supervision of one of the institutes involved in the course of studies. In addition to the elaboration of a scientific question, the Project Work gives space to select suitable scientific methods in order to obtain scientific results in test and laboratory series, which have to be questioned. The results of the Project Work will presented to the Support personnel. The Project work prepared for the following Master Thesis. The Workload amounts to 300 hours.

Vorkenntnisse

Eine erste wissenschaftliche Arbeit, in der Regel die Bachelor- oder Diplomarbeit

Literatur

Diverse

Besonderheit

Für die erfolgreiche Präsentation der Studienarbeit erhalten Sie als Studienleistung 1 LP. Abweichend vom Studiengang Maschinenbau haben die anderen Masterstudiengänge der Fakultät für Maschinenbau nachfolgende Verantwortliche Personen: Mechatronik und Robotik: Alle Institute der Fakultät für Maschinenbau und der Fakultät für Elektrotechnik und Informatik sowie der Fakultät für Bauingenieurwesen und Geodäsie. Optische Technologien: Fakultät für Mathematik und Physik und Fakultät für Maschinenbau. Biomedizintechnik: Fakultät für Maschinenbau und ausgewählte Professoren*innen der Fakultät für Elektrotechnik und Informatik.

Modulname	Ultrakurze Laserpulse		
Modulname EN	Ultrashort laser pulses		
Verantw. Dozent/-in	Morgner	Semester	SoSe
Institut	Institut für Quantenoptik	ECTS	2
Art	<input type="checkbox"/> Pflicht <input type="checkbox"/> Wahlpflicht <input checked="" type="checkbox"/> Wahl <input type="checkbox"/> Studium generale / Tutorien		
Vertiefungsrichtung	Optional Modules	Prüfungsform	schriftlich
Präsenzstudienzeit	30	Selbststudienzeit	30
		Kursumfang	V2
Modulbeschreibung			
Representation of ultrashort light pulses Propagation equations, Causality and dispersion, Origin of the refractive index Propagation in dispersive media, Pulse front distortions, Chirp management: Angular dispersion, Chirped mirrors, Pulse shapers Ultrafast nonlinear optics: Second-order effects, Phase matching, Broadband frequency conversion, OPA; Third-order effects: SPM, Self-focusing, Propagation in waveguides, Solitons, Filamentation Pulse characterization Ultrashort pulse generation: Resonators, Laser dynamics, Relaxation oscillations, Q-switching, Mode locking Short pulse amplification, High-energy laser systems			
Vorkenntnisse			
Zwingend: Optik, Atomphysik und Quantenphänomene; Empfohlen: Kohärente Optik			
Literatur			
D. Meschede: Optik, Licht und Laser, Vieweg+Teubner, 3. Aufl. 2008.			
Besonderheit			
The course's name on Stud.IP is "Ultrakurze Laserpulse"			

Appendix

Objectives table of the master program Optical Technologies

Important study goals	Competency goals in the sense of learning outcomes	Corresponding modules
Basic knowledge of physics	Basic principles (engineers) and further education (physicist) in the field of optics and related fields	Biophotonics Laser Spectroscopy in Life Sciences Optical Coatings Photonics
Basic knowledge of engineering sciences	Basics (physicists) or specialization (engineers) in engineering sciences	Design of Optical Systems Automotive Lighting Optical Metrology Augmented Reality Apps for Mechatronics and Medical Technology
Immersion or specialization in Optical Technologies	Getting detailed knowledge about modern optical technologies provided by a wide range of optic concerning lectures.	Compare selective module descriptions.

Diploma Supplement

This Diploma Supplement model was developed by the European Commission, Council of Europe and UNESCO/CEPES. The purpose of the supplement is to provide sufficient independent data to improve the international 'transparency' and fair academic and professional recognition of qualifications (diplomas, degrees, certificates etc.). It is designed to provide a description of the nature, level, context, content and status of the studies that were pursued and successfully completed by the individual named on the original qualification to which this supplement is appended. It should be free from any value judgements, equivalence statements or suggestions about recognition. Information in all eight sections should be provided. Where information is not provided, an explanation should give the reason why.

Diploma Supplement

1. HOLDER OF THE QUALIFICATION

1.1 Family Name / 1.2 First Name

1.3 Date, Place of Birth

1.4 Student ID Number or Code

2. QUALIFICATION

2.1 Name of Qualification (full, abbreviated; in original language)

Master of Science in Optical Technologies, MSc

Master of Science in Optische Technologien

Title Conferred (full, abbreviated; in original language)

Master of Science, MSc

2.2 Main Field(s) of Study

Mechanical Engineering, Physics

2.3 Institution Awarding the Qualification (in original language)

Gottfried Wilhelm Leibniz Universität Hannover

Fakultät für Maschinenbau

Status (Type / Control)

University / State Institution

2.4 Institution Administering Studies (in original language)

[same]

Status (Type / Control)

[same]

2.5 Language(s) of Instruction/Examination

German

3. LEVEL OF THE QUALIFICATION

3.1 Level

Second degree, research-oriented, including Master's thesis

3.2 Official Length of Programme

Two years, 120 ECTS Credit Points

3.3 Access Requirements

Bachelor degree in Mechanical Engineering, Physics, Electrical Engineering or an equivalent first degree or foreign equivalent (see Sec. 8.4)

4. CONTENTS AND RESULTS GAINED

4.1 Mode of Study

Full-time programme

4.2 Programme Requirements/Qualification Profile of the Graduate

4.2.1 Qualification targets Master's in Optical Technologies – Knowledge, Skills, Competencies

The degree course enables graduates to solve problems and to address issues in the field of optical technologies. In compulsory subjects, students on the programme learn not only engineering methods for solving problems and addressing issues, but also important principles of physics relevant to optical technologies. Elective competence areas round off the theoretical physics training with topics specific to engineering.

Practical training in the form of laboratory experiments and work experience in industry prepare students for their professional life in research firms in the optical industry. By writing a project report and a Master's thesis, students acquire the skills required for conducting independent project work. The primary goals of this work include gaining experience in the planning and implementation of projects as well as learning how to draw up correct project documentation and presenting project results.

4.2.2 Learning results

Graduates of the Master's programme are expected to have broad knowledge of optical technologies. To this end, students are taught knowledge, skills and methods that represent the state of the art, due to the high level of research conducted by the faculties involved.

Industry internships, laboratory and project work, and the Master's thesis enable students to gain experience in managing their own projects, working in a team, and exercising scientific responsibility within research activities.

In order to achieve these goals, the Master's programme is divided into a basic field and several advanced optional fields. The basic field consists of field A "Physics" and field B "Engineering".

4.4 Grading Scheme

See grading scheme in Sec. 8.6

4.5 Overall Classification (in original language)
«MPO_Gesamtnote_eng»

Based on weighted average of grades in examination fields.

$$\text{Overall grade} = \frac{\begin{array}{l} \text{(Grade for the examination x respective CP)} \\ + \text{(grade for the project work x10 CP)} \\ + \text{(grade for the Master's thesis x30 CP)} \end{array}}{\text{Sum of CP for all graded examinations}}$$

5. FUNCTION OF THE QUALIFICATION

5.1 Access to Further Study

The Master's degree qualifies the graduate to apply for admission to doctoral studies.

5.2 Professional Status

The Master's degree is the second degree in Mechanical Engineering that qualifies for a professional and scientific career.

6. ADDITIONAL INFORMATION

6.1 Additional Information

The Master of Science in Optical Technologies was accredited in 2014 by ASIIN (Accreditation Agency for Programmes in Engineering, Computer Science, Natural Sciences and Mathematics, www.asiin-ev.de).

6.2 Further Information Sources

About the university: www.uni-hannover.de

About the faculty: <http://www.maschinenbau.uni-hannover.de/>

About the study programme: <http://www.maschinenbau.uni-hannover.de/480.html>

Student Advice Service: <http://www.uni-hannover.de/de/studium/studienfuehrer/optische-tech/>

Contact:

Der Dekan der Fakultät für Maschinenbau

der Leibniz Universität Hannover

An der Universität 1

30823 Garbsen

Tel.+49-511-762-2779

7. CERTIFICATION

This Diploma Supplement refers to the following original documents:

Urkunde über die Verleihung des Grades vom [Date]

Prüfungszeugnis vom [Date]

Certification Date:

(Official Stamp/Seal)

Chairman Examination Committee

8. NATIONAL HIGHER EDUCATION SYSTEM

The information on the national higher education system on the following pages provides a context for the qualification and the type of higher education that awarded it.

8. INFORMATION ON THE GERMAN HIGHER EDUCATION SYSTEM¹

8.1 Types of Institutions and Institutional Status

Higher education (HE) studies in Germany are offered at three types of Higher Education Institutions (HEI).²

- *Universitäten* (Universities) including various specialized institutions, offer the whole range of academic disciplines. In the German tradition, universities focus in particular on basic research so that advanced stages of study have mainly theoretical orientation and research-oriented components.

- *Fachhochschulen* (Universities of Applied Sciences) concentrate their study programmes in engineering and other technical disciplines, business-related studies, social work, and design areas. The common mission of applied research and development implies a distinct application-oriented focus and professional character of studies, which include integrated and supervised work assignments in industry, enterprises or other relevant institutions.

- *Kunst- und Musikhochschulen* (Universities of Art/Music) offer studies for artistic careers in fine arts, performing arts and music; in such fields as directing, production, writing in theatre, film, and other media; and in a variety of design areas, architecture, media and communication.

Higher Education Institutions are either state or state-recognized institutions. In their operations, including the organization of studies and the designation and award of degrees, they are both subject to higher education legislation.

8.2 Types of Programmes and Degrees Awarded

Studies in all three types of institutions have traditionally been offered in integrated "long" (one-tier) programmes leading to *Diplom-* or *Magister Artium* degrees or completed by a *Staatsprüfung* (State Examination).

Within the framework of the Bologna-Process one-tier study programmes are successively being replaced by a two-tier study system. Since 1998, a scheme of first- and second-level degree programmes (Bachelor and Master) was introduced to be offered parallel to or instead of integrated "long" programmes. These programmes are designed to provide enlarged variety and flexibility to students in planning and pursuing educational objectives, they also enhance international compatibility of studies.

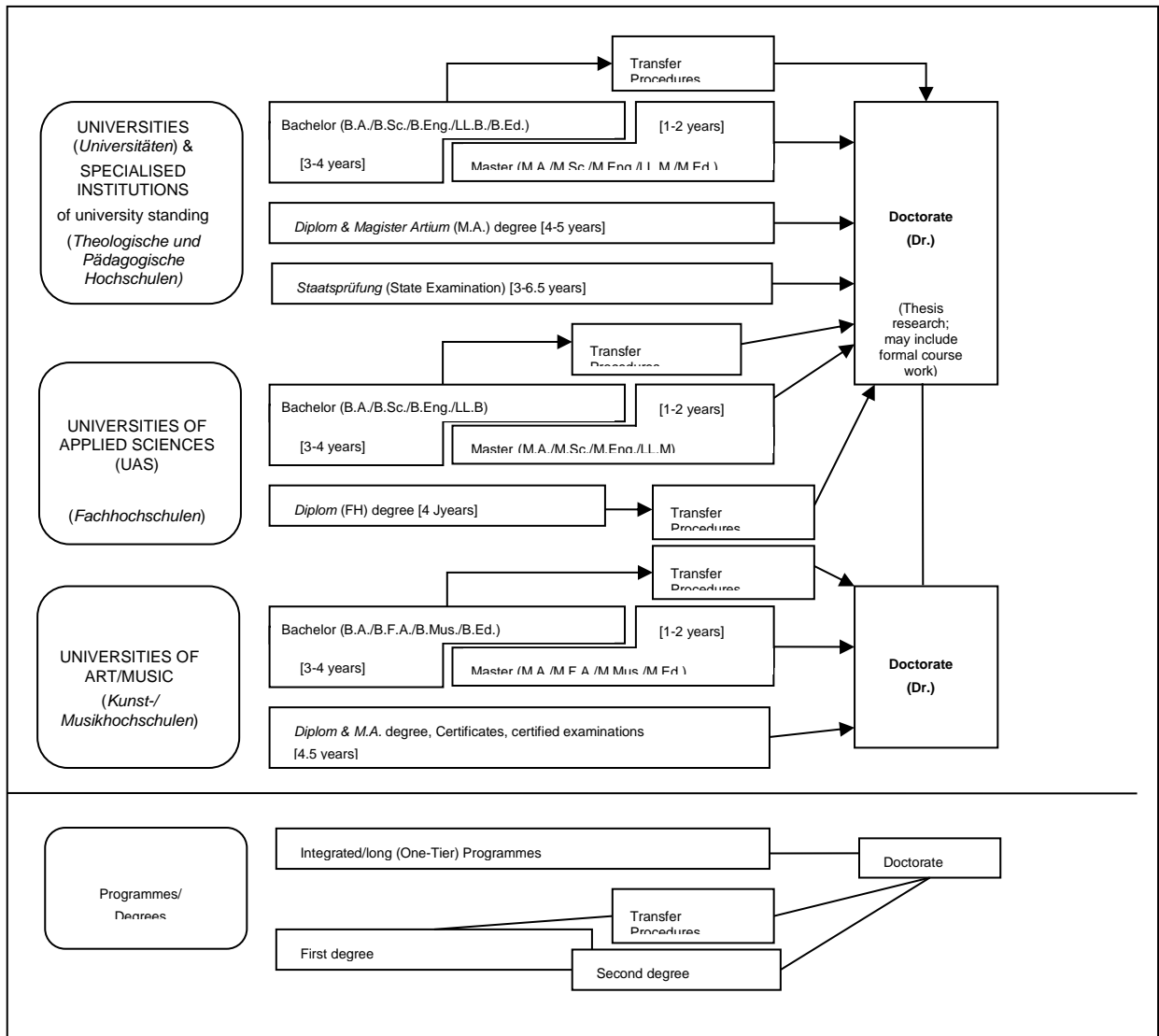
The German Qualification Framework for Higher Education Degrees³ describes the degrees of the German Higher Education System. It contains the classification of the qualification levels as well as the resulting qualifications and competencies of the graduates.

For details cf. Sec. 8.4.1, 8.4.2, and 8.4.3 respectively. Table 1 provides a synoptic summary.

8.3 Approval/Accreditation of Programmes and Degrees

To ensure quality and comparability of qualifications, the organization of studies and general degree requirements have to conform to principles and regulations established by the Standing Conference of the Ministers of Education and Cultural Affairs of the *Länder* in the Federal Republic of Germany (KMK).⁴ In 1999, a system of accreditation for programmes of study has become operational under the control of an Accreditation Council at national level. All new programmes have to be accredited under this scheme; after a successful accreditation they receive the quality-label of the Accreditation Council.⁵

Table 1: Institutions, Programmes and Degrees in German Higher Education



8.4 Organization and Structure of Studies

The following programmes apply to all three types of institutions. Bachelor's and Master's study courses may be studied consecutively, at various higher education institutions, at different types of higher education institutions and with phases of professional work between the first and the second qualification. The organization of the study programmes makes use of modular components and of the European Credit Transfer and Accumulation System (ECTS) with 30 credits corresponding to one semester.

8.4.1 Bachelor

Bachelor degree study programmes lay the academic foundations, provide methodological skills and lead to qualifications related to the professional field. The Bachelor degree is awarded after 3 to 4 years.

The Bachelor degree programme includes a thesis requirement. Study courses leading to the Bachelor degree must be accredited according to the Law establishing a Foundation for the Accreditation of Study Programmes in Germany.⁶

First degree programmes (Bachelor) lead to Bachelor of Arts (B.A.), Bachelor of Science (B.Sc.), Bachelor of Engineering (B.Eng.), Bachelor of Laws (LL.B.), Bachelor of Fine Arts (B.F.A.), Bachelor of Music (B.Mus.) or Bachelor of Education (B.Ed.).

8.4.2 Master

Master is the second degree after another 1 to 2 years. Master study programmes may be differentiated by the profile types "practice-oriented" and "research-oriented". Higher Education Institutions define the profile.

The Master degree study programme includes a thesis requirement. Study programmes leading to the Master degree must be accredited according to the Law establishing a Foundation for the Accreditation of Study Programmes in Germany.⁷

Second degree programmes (Master) lead to Master of Arts (M.A.), Master of Science (M.Sc.), Master of Engineering (M.Eng.), Master of Laws (L.L.M.), Master of Fine Arts (M.F.A.), Master of Music (M.Mus.) or Master of Education (M.Ed.). Master study programmes which are designed for continuing education may carry other designations (e.g. MBA).

8.4.3 Integrated "Long" Programmes (One-Tier):

Diplom degrees, Magister Artium, Staatsprüfung

An integrated study programme is either mono-disciplinary (*Diplom* degrees, most programmes completed by a *Staatsprüfung*) or comprises a combination of either two major or one major and two minor fields (*Magister Artium*). The first stage (1.5 to 2 years) focuses on broad orientations and foundations of the field(s) of study. An Intermediate Examination (*Diplom-Vorprüfung* for *Diplom* degrees; *Zwischenprüfung* or credit requirements for the *Magister Artium*) is prerequisite to enter the second stage of advanced studies and specializations. Degree requirements include submission of a thesis (up to 6 months duration) and comprehensive final written and oral examinations. Similar regulations apply to studies leading to a *Staatsprüfung*. The level of qualification is equivalent to the Master level.

- Integrated studies at *Universitäten (U)* last 4 to 5 years (*Diplom* degree, *Magister Artium*) or 3 to 6.5 years (*Staatsprüfung*). The *Diplom* degree is awarded in engineering disciplines, the natural sciences as well as economics and business. In the humanities, the corresponding degree is usually the *Magister Artium* (M.A.). In the social sciences, the practice varies as a matter of institutional traditions. Studies preparing for the legal, medical and pharmaceutical professions are completed by a *Staatsprüfung*. This applies also to studies preparing for teaching professions of some *Länder*. The three qualifications (*Diplom*, *Magister Artium* and *Staatsprüfung*) are academically equivalent. They qualify to apply for admission to doctoral studies. Further prerequisites for admission may be defined by the Higher Education Institution, cf. Sec. 8.5.

- Integrated studies at *Fachhochschulen (FH)*/Universities of Applied Sciences (UAS) last 4 years and lead to a *Diplom (FH)* degree. While the *FH/UAS* are non-doctorate granting institutions, qualified graduates may apply for admission to doctoral studies at doctorate-granting institutions, cf. Sec. 8.5.

- Studies at *Kunst- and Musikhochschulen* (Universities of Art/Music etc.) are more diverse in their organization, depending on the field and individual objectives. In addition to *Diplom/Magister* degrees, the integrated study programme awards include Certificates and certified examinations for specialized areas and professional purposes.

8.5 Doctorate

Universities as well as specialized institutions of university standing and some Universities of Art/Music are doctorate-granting institutions. Formal prerequisite for admission to doctoral work is a qualified Master (UAS and U), a *Magister* degree, a *Diplom*, a *Staatsprüfung*, or a foreign equivalent. Particularly qualified holders of a Bachelor or a *Diplom (FH)* degree may also be admitted to doctoral studies without acquisition of a further degree by means of a procedure to determine their aptitude. The universities respectively the doctorate-granting institutions regulate entry to a doctorate as well as the structure of the procedure to determine aptitude. Admission further requires the acceptance of the Dissertation research project by a professor as a supervisor.

8.6 Grading Scheme

The grading scheme in Germany usually comprises five levels (with numerical equivalents; intermediate grades may be given): "*Sehr Gut*" (1) = Very Good; "*Gut*" (2) = Good; "*Befriedigend*" (3) = Satisfactory; "*Ausreichend*" (4) = Sufficient; "*Nicht ausreichend*" (5) = Non-Sufficient/Fail. The minimum passing grade is "*Ausreichend*" (4). Verbal designations of grades may vary in some cases and for doctoral degrees.

In addition institutions partly already use an ECTS grading scheme.

8.7 Access to Higher Education

The General Higher Education Entrance Qualification (*Allgemeine Hochschulreife, Abitur*) after 12 to 13 years of schooling allows for admission to all higher educational studies. Specialized variants (*Fachgebundene Hochschulreife*) allow for admission to particular disciplines. Access to *Fachhochschulen* (UAS) is also possible with a *Fachhochschulreife*, which can usually be acquired after 12 years of schooling. Admission to Universities of Art/Music may be based on other or require additional evidence demonstrating individual aptitude.

Higher Education Institutions may [in certain cases](#) apply additional admission procedures.

8.8 National Sources of Information

- *Kultusministerkonferenz (KMK)* [Standing Conference of the Ministers of Education and Cultural Affairs of the *Länder* in the Federal Republic of Germany]; Lennéstrasse 6, D-53113 Bonn; Fax: +49[0]228/501-229; Phone: +49[0]228/501-0
- Central Office for Foreign Education (ZaB) as German NARIC; www.kmk.org; E-Mail: zab@kmk.org
- "Documentation and Educational Information Service" as German EURYDICE-Unit, providing the national dossier on the education system
<http://www.kmk.org/dokumentation/zusammenarbeit-auf-europaeischer-ebene-im-eurydice-informationsnetz.html>; E-Mail: eurydice@kmk.org
- *Hochschulrektorenkonferenz (HRK)* [German Rectors' Conference]; Ahrstrasse 39, D-53175 Bonn; Fax: +49[0]228/887-110; Phone: +49[0]228/887-0; www.hrk.de; E-Mail: post@hrk.de
- "Higher Education Compass" of the German Rectors' Conference features comprehensive information on institutions, programmes of study, etc. (www.higher-education-compass.de)

¹ The information covers only aspects directly relevant to purposes of the Diploma Supplement. All information as of 1 July 2010.

² *Berufsakademien* are not considered as Higher Education Institutions, they only exist in some of the *Länder*. They offer educational programmes in close cooperation with private companies. Students receive a formal degree and carry out an apprenticeship at the company. Some *Berufsakademien* offer Bachelor courses which are recognized as an academic degree if they are accredited by a German accreditation agency.

³ German Qualification Framework for Higher Education Degrees (Resolution of the Standing Conference of the Ministers of Education and Cultural Affairs of the *Länder* in the Federal Republic of Germany of 21.04.2005).

⁴ Common structural guidelines of the *Länder* for the accreditation of Bachelor's and Master's study courses (Resolution of the Standing Conference of the Ministers of Education and Cultural Affairs of the *Länder* in the Federal Republic of Germany of 10.10.2003, as amended on 04.02.2010).

⁵ "Law establishing a Foundation 'Foundation for the Accreditation of Study Programmes in Germany'", entered into force as from 26.2.2005, GV. NRW. 2005, nr. 5, p. 45 in connection with the Declaration of the *Länder* to the Foundation "Foundation: Foundation for the Accreditation of Study Programmes in Germany" (Resolution of the Standing Conference of the Ministers of Education and Cultural Affairs of the *Länder* in the Federal Republic of Germany of 16.12.2004).

⁶ See note No. 5.

⁷ See note No. 5.