STUDIENDEKANAT MASCHINENBAU

Leibniz Universität Hannover

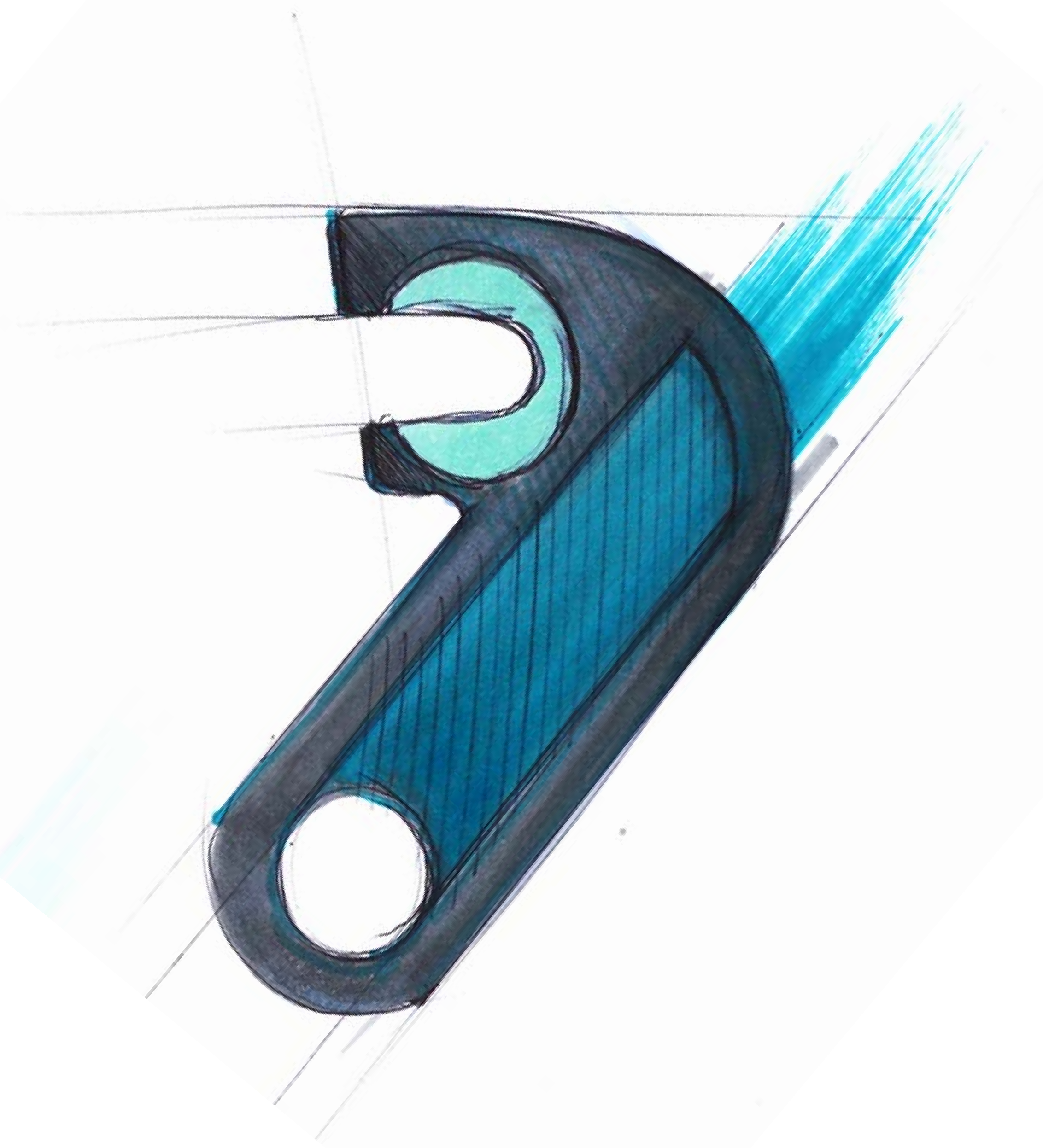
Module Catalog for PO 2017

Study Guide for the study program
Optical Technologies

Bachelor of Science

Master of Science

academic year 17/18



Impressum

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www.hot.uni-hannover.de

Valid for the winter semester 2017/2018
Hannover, 27.09.2017

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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.-Ing. Stephan Kabelac

Dean of studies of the faculty of mechanical engineering.

Prof. Dr. habil. Bernhard Roth

Scientific and managing director, Hannover Centre for Optical Technologies (HOT).

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	20 CP
Optional courses	35 CP
Master Lab	5 CP
Studium Generale and Tutorials	4 CP
Student Project	10 CP
Internship (12 weeks)	15 CP
Master Thesis	30 CP

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.

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 lehre@hot.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

<table>
<tr><th>CP</th><th>1st term</th><th>2nd term</th><th>3rd term</th><th>4th term</th></tr>
<tr><td>1</td><td rowspan="5">Photonics
Compulsory Module
(5 CP)</td><td rowspan="5">Design and Simulation of optomechatronic Systems
Compulsory Module
(5 CP)</td><td rowspan="10">Student Project
(10 CP)</td><td rowspan="30">Master Thesis
(30 CP)</td></tr>
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<tr><td>6</td><td rowspan="5">Optical Measurement Technology
Compulsory Module
(5 CP)</td><td rowspan="20">Optional Modules
(20 CP)</td></tr>
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<tr><td>11</td><td rowspan="5">Laser Spectroscopy in Life Sciences
Compulsory Module
(5 CP)</td><td rowspan="15">Advanced Internship
(15 CP)</td></tr>
<tr><td>12</td></tr>
<tr><td>13</td></tr>
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<tr><td>15</td></tr>
<tr><td>16</td><td rowspan="15">Optional Modules
(15 CP)</td></tr>
<tr><td>17</td></tr>
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<tr><td>26</td><td rowspan="5">Master Lab Tutorial
(5 CP)</td><td>Project Pres. (1 CP)</td></tr>
<tr><td>27</td><td rowspan="4">Studium Generale / Tutorials
(4 CP)</td></tr>
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</table>

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 Hannover Centre for Optical Technologies (HOT) 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	Rahlves	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

Module	Responsible	Sem.	Credits
Atomic Optics	Ospelkaus	SS	4
Augmented Reality Apps for Mechatronics and Medical Engineering	Kahrs	SS/WS	4
Automotive Lighting	Wallaschek	WS	5
Biophotonics – Imaging Physics and Manipulation of Biological Cells	Heisterkamp	SS	4
Computational Photonics	Demircan	SS	6
Detection and Quantification of Optical Radiation	Kovacev	SS	--
Digital Image Processing	Gigengack	SS	5
Fundamentals and Configuration of Laser Beam Sources	Overmeyer Kracht	WS	5

Fundamentals of Laser Medicine and Biophotonics	Lubatschowski Krüger	WS	5
Laser Interferometry	Heinzel	WS/SS	3
Laser Material Processing II	Overmeyer	SS	5
Laser Measurement Technology	Roth	SS	5
Nonlinear Optics	Demircan	SS	5
Optical Coatings and Layers	Ristau	WS	4
Optical properties of micro and nano structures	Wolfer	WS	4
Photogrammetric Computer Vision	Heipke	WS	5
Physics of Solar Cells	Brendel, Altermatt	SS	6
Production of Optoelectronic Systems	Overmeyer	WS	5
Proseminar Biophotonics	Roth	WS/SS	3
Proseminar Nonlinear Fiber Optics	Demircan	SS	3
Radar Remote Sensing	Motagh	SS	3
Satellite Remote Sensing I	Melsheimer	WS	4
Satellite Remote Sensing II	Melsheimer	SS	4
Seminar Numerical Optics	Roth	SS	3
Seminar Theory and practice of optical functional layers	Ristau	SS	3
Solid State Lasers	Weßels	SS	2
Ultrashort Laser Pulses	Babushkin	SS	4
XUV Laser Physics	Kovacev	WS	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: • Einführung in die Festkörperphysik *This module can only acknowledged once! Students who are affected have to attend an additional course to match their ECTS-goal!*	Weßels	SS	/
Optics, atomic and quantum physics Replaces the mandatory modules: • 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.

Atomic Optics

Atomoptik

Title:	Atomoptik
Type:	Lecture
Number:	13084
Lecturer:	Prof. Dr. Silke Ospelkaus, Prof. Dr. Christian Ospelkaus
Institute:	Institut für Quantenoptik
Email:	

Event description:

Recent experimental procedures to investigate the physics of ultracold gases, lasermanipulation 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

Prior knowledge

Atom and Molecular Physics, Quantumoptics

Recommended literature

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

Van der Straaten

Additional Information

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Presence studies time:	--	**Type of exam**	--	**Course content**	L2/E1
Self-study:	--	**ECTS-CP:**	4	**Semester**	SS

Augmented Reality Apps for Mechatronics and Medical Technology

Augmented Reality Apps für Mechatronik und Medizintechnik

Title:	Augmented Reality Apps für Mechatronik und Medizintechnik
Type:	Lecture
Number:	--
Lecturer:	Dr.-Ing. Lüder A. Kahrs
Institute:	Institut für Mechatronische Systeme, www.imes.uni-hannover.de
Email:	lueder.kahrs@imes.uni-hannover.de

Event description:

The course comprises development of apps for mobile devices in the field of mechatronics and medical technology. The target operating system is Android. A special focus is the usage of display and camera for augmented reality scenarios. Image processing and visualization techniques are important side aspects. The students will get insights of the IDE Android Studio and the library Vuforia. Further topics of the course are visualization concepts, mixed reality, object recognition, navigation, etc.

Prior knowledge

Required knowledge: Programing under Java, C or C++

Recommended literature

Slides, Online tutorials for Android Programming

Additional Information

The course is limited to 10 teams of 2 students each.

Presence studies time:	32h	**Type of exam:**	oral	**Course content**	L2/E1
Self-study:	88h	**ECTS-CP:**	4	**Semester**	WS/SS

Automotive Lighting

Kraftfahrzeug - Lichttechnik

Title:	Automotive Lighting
Type:	Lecture
Number:	33378
Lecturer:	Prof. Dr.-Ing. Jörg Wallaschek, Prof. Dr.-Ing Roland Lachmeyer
Institute:	Institut für Dynamik und Schwingungen, www.ids.uni-hannover.de
Email:	wallaschek@ids.uni-hannover.de

Event description:

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 sense complete the course.

Contents:

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

Prior knowledge

Recommended literature

Wördenweber, B.; Wallaschek, J.; Boyce, P.; Hoffman, D.: Automotive Lighting and Human Vision, Springer-Verlag, Berlin, Heidelberg 2007

Additional Information

The course consists of three parts: 1) a series of 6 introductive lectures as well as a practical training in light measurement technology, 2) preparation of lectures and the according presentation by the students their selves, 3) an excursion to a company or research facility in the field of vehicle lighting, e.g. Volkswagen AG in Wolfsburg, Hella or the L-LAB in Lippstadt.

Presence studies time:	32h	**Type of exam:**	oral	**Course content**	L2
Self-study:	88h	**ECTS-CP:**	5	**Semester**	WS

Biophotonics – Imaging and Manipulation of Biological Cells

Biophotonik – Bildgebung und Manipulation von biologischen Zellen

Title:	Biophotonik – Bildgebung und Manipulation von biologischen Zellen
Type:	Lecture
Number:	13144
Lecturer:	Prof. Dr. Alexander Heisterkamp
Institute:	Laser Zentrum Hannover e.V. and Institut für Quantenoptik
Email:	a.heisterkamp@lzh.de

Event description:

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 the IQ, in which the relevant article will be discussed.

Prior knowledge

Basic knowledge in coherent optics

Possibly Fundamentals of Lasers in Medicine and Biomedical Optics (WS), Laserphysics

Recommended literature

Basic Methods in Microscopy, Spector, Goldman
Introduction to Biophotonics, P.N. Prasad
Laser Manipulation of Cells and Tissues, M.W. Berns, K. O. Greulich
Atala, Lanza, Thomson, Nerem: Principles of Regenerative Medicine
Original literature

Additional Information

Limited places in tutorial (30) (PC workstations at the RRZN)

Presence studies time:	45h	**Type of exam:**	written /oral	**Course content**	L2
Self-study:	30h	**ECTS-CP:**	4	**Semester**	SS

Computational Photonics

Computational Photonics

Title:	Computational Photonics
Type:	Lecture
Number:	13149
Lecturer:	Ihar Babushkin, Ayhan Demircan, Oliver Melchert, Uwe Morgner
Institute:	Institut für Quantenoptik, www.iqo.uni-hannover.de
Email:	demircan@iqo.uni-hannover.de

Event description:

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.

Inhalt:

- Light-matter interaction (Chromatic and geometric dispersion, second- and third-order susceptibility, Raman scattering, supercontinuum generation, multiphoton und tunneling ionization, low-order harmonic radiation)
- Laserdynamics (Mode-locking, Rate equation, Q-switching)
- 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
- Optimization algorithms
- Spectral and Pseudospectral methods
- Runge-Kutta and operator splitting approach
- Parallel computing (openMP, openMPI)

Prior knowledge

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Recommended literature

Obayya, „Computational Photonics“, Wiley

Additional Information

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Presence studies time:	60h	**Type of exam:**	written /oral	**Course content**	L2/E2
Self-study:	90h	**ECTS-CP:**	6	**Semester**	SS

Design and Simulation of Optomechatronic Systems

Konstruktion Optischer Systeme / Optischer Gerätebau

Title:	Konstruktion Optischer Systeme / Optischer Gerätebau
Type:	Lecture
Number:	31308
Lecturer:	Prof. Dr.-Ing. Lachmayer, Dr.-Ing. Alexander Wolf
Institute:	Institut für Produktentwicklung und Gerätebau, www.ipeg.uni-hannover.de
Email:	wolf@ipeg.uni-hannover.de

Event description:

The course Design of Optical Systems provides knowledge about the specific design and manufacturing process of optical devices. The path of the light is considered from various light sources over different light shaping and modifying optical elements to the perception by the human eye. The course focuses on the methodological construction process, product development and optimization. Practical examples arise from vehicle lighting and connections to manufacturing technology and metrology. Exercises with optical simulation software complete the event.

Prior knowledge

Lecture Technical Mechanics III

Recommended literature

Lecture script

Additional Information

Presence studies time:	32h	**Type of exam:**	written/ oral	**Course content**	L2/E1
Self-study:	118 h	**ECTS-CP:**	5	**Semester**	SS

Detection and Quantification of Optical Radiation

Detection and Quantification of Optical Radiation

Title:	Detection and Quantification of Optical Radiation
Type:	Lecture + Lab
Number:	12532 (Lecture), 12413 (Lab)
Lecturer:	Prof. Milutin Kovacev
Institute:	Institut für Quantenoptik
Email:	

Event Description:

Contents:

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

Example projects;

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

Prior knowledge

Recommended Literature

Additional Information

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.

Presence studies time:	--	**Type of exam:**	--	**Course content**	---
Self-Study	--	**ECTS-CP:**	--	**Semester**	SS

Digital Image Processing

Digitale Bildverarbeitung

Title:	Digitale Bildverarbeitung
Type:	Lecture
Number:	36428
Lecturer:	Dr. rer. nat. Fabian Gigengack
Institute:	Institut für Informationsverarbeitung
Email:	

Event description

The students are familiar with two-dimensional discrete systems, scanning, the basics of visual perception, discrete geometry, image restoration, image processing and image analysis.

Contents:

- Fundamentals
- Linear System Theory
- Image Description
- Discrete geometry
- Color and texture
- Transformations
- Image Editing
- Image restoration
- Image Coding
- Image analysis

Prior knowledge

Engineering mathematics, digital signal processing (recommended)

Recommended literature

Jähne, Haußecker, Geißler: Handbook of Computer Vision and Applications, Academic Press, 1999
Jähne, Bernd: Digitale Bildverarbeitung, Springer Verlag, 1997
Haberäcker, Peter: Praxis der Digitalen Bildverarbeitung und Mustererkennung, Carl Hanser Verlag, 1995
Abmayr, Wolfgang: Einführung in die digitale Bildverarbeitung, Teubner Verlag, 1994
Pinz, Axel: Bildverstehen, Springer Verlag, 1994
Ohm, Jens-Rainer: Digitale Bildcodierung, Springer Verlag, 1995
Girod, Rabenstein, Stenger: Einführung in die Systemtheorie, Teubner Verlag, 1997

Additional information

Short testat

Presence studies time:	--	**Type of exam:**	written	**Course cont.**	L2/E1/ Lab
Self-study:	--	**ECTS-CP:**	5	**Semester**	SS

Fundamentals and Configuration of Laser Beam Sources

Grundlagen und Aufbau von Laserstrahlquellen

Title:	Grundlagen und Aufbau von Laserstrahlquellen
Type:	Lecture
Number:	30275
Lecturer:	Prof. Dr.-Ing. Ludger Overmeyer, Dr. Dietmar Kracht
Institute:	Institut für Transport- und Automatisierungstechnik, www.ita.uni-hannover.de Laserzentrum Hannover, www.lzh.de
Email:	d.kracht@lzh.de

Event description:

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Contents:

- Fundamentals of laser beam sources
- Operation regime of lasers
- Characterization of lasers
- Laser diodes
- Optical resonators
- CO2-lasers
- Excimer lasers
- Concepts and materials for lasers
- Rod and disk lasers
- Fiber lasers and amplifiers
- Frequency conversion
- Ultrashort pulse lasers

Prior knowledge

Basic knowledge in coherent optics

Recommended literature

Lecture Script; Further recommendations in lecture

Additional Information

Multiple experimental demonstrations in the laboratories of Laser Zentrum Hannover e.V.

Presence studies time:	32h	**Type of exam:**	oral/written	**Course content**	L2/E1
Self-study:	118 h	**ECTS-CP:**	5	**Semester**	WS

Fundamentals of Laser Medicine and Biophotonics

Grundlagen der Lasermedizin und Biophotonik

Title:	Grundlagen der Lasermedizin und Biophotonik
Type:	Lecture
Number:	12130
Lecturer:	apl. Prof. Dr. Holger Lubaschowski, Prof. Dr. Alexander Heisterkamp
Institute:	Institut für Quantenoptik, www.iqo.uni-hannover.de
Email:	a.krueger@lzh.de

Event description:

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, theragnostics
- Clinical examples

Prior knowledge

Coherent Optics, Photonics or Nonlinear Optics

Recommended literature

Eichler, Seiler: "Lasertechnik in der Medizin"; Springer-Verlag

Welch, van Gemert: "Optical-Thermal Response of Laser-Irradiated Tissue"; Plenum Press

Berlien, Müller: "Angewandte Lasermedizin"; Bd. 1,2, eco med Verlag

Berlien, Müller: "Applied Laser Medicine"; Springer-Verlag

Berns, Greulich: "Laser Manipulation of Cells and Tissues"; Academic Press

Additional Information

5 ECTS-CP for lecture + seminar, limited places for talks in block seminar (20 talks), participation in lecture and seminar not limited (4 ECTS)

Presence studies time:	22h	**Type of exam:**	written/ oral	**Course content**	L2
Self-study:	128 h	**ECTS-CP:**	4+1	**Semester**	WS

Laser Interferometry

Laserinterferometrie

Title:	Laserinterferometrie
Type:	Lecture
Number:	12412
Lecturer:	apl. Prof. Gerhard Heinzel
Institute:	Institut für Gravitationsphysik, www.aei.mpg.de
Email:	gerhard.heinzel@aei.mpg.de

Event description:

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 Gaussion rays and higher methods
- Transformation of Gaussian rays
- Selection procedures: internal, external and Schnuppmodulation; Pound-Drever Hall procedure
- Polarization
- Tranfer function and control loops

Applications: GEO600, LISA, GRACE Follow-On

Prior knowledge

Coherent Optics, nonlinear Optics

Recommended literature

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

Additional Information

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Presence studies time:	32h	**Type of exam:**	exam	**Course content**	L2/E1
Self-study:	58h	**ECTS-CP:**	3	**Semester**	WS/SS

Laser Material Processing II

Lasermaterialbearbeitung

Title:	Laser Material Processing II
Type:	Lecture
Number:	32236
Lecturer:	Prof. Dr.-Ing. Ludger Overmeyer, Yixiao Wang
Institute:	Institut für Transport- und Automatisierungstechnik, www.ita.uni-hannover.de
Email:	Yixiao.wang@ita.uni-hannover.de

Event description:

The course covers the spectrum of laser technology in the production as well as the potential of laser technology for future applications. We explain the scientific and technical basic knowledge, which is used in the laser systems as well as in the interaction of the beam with different materials. On the basis of applications in subject areas such as micromachining, the required physical conditions for laser processing such as wavelength, fluence, pulse peak power, are worked out and described in connection with the specific process, handling and control technology. The purpose is to develop an understanding of the basics and the current demands for laser technology to provide an access for the participants into laser technology in industry.

Prior knowledge

Basic optics, Light sources II

Recommended literature

Recommendation made in the lecture; lecture script

Additional Information

Lectures and exercises seminars in the rooms of Laser Zentrum Hannover e.V. (Laboratory/test areas)

Presence studies time:	32h	**Type of exam:**	oral	**Course content**	L2/E1
Self-study:	118 h	**ECTS-CP:**	5	**Semester**	SS

Laser Measurement Technology

Lasermesstechnik

Title:	Laser Measurement Technology
Type:	Lecture
Number:	33010 (Lecture), 33012 (Exercise)
Lecturer:	Prof. Dr. Bernhard Roth
Institute:	Hanover Centre for Optical Technologies, HOT, www.hot.uni-hannover.de
Email:	bernhard.roth@hot.uni-hannover.de

Event description:

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
- Laser spectrometry
- Holographic measurement techniques
- Ultra-short laser pulse measurement techniques
- Application in measurement, monitoring, and sensing

Prior knowledge

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

Recommended literature

Donges, Noll, Laser Measurement Technology: Fundamentals and Applications, Springer (2015)

Hugenschmidt, Lasermesstechnik: Diagnostik der Kurzzeitphysik, Berlin, Heidelberg Springer-Verlag, 2007

Additional Information

Recommended for second semester and higher (Master course)

Presence studies time:	32h	**Type of exam:**	written/ oral	**Course content**	L2/E1
Self-study:	118 h	**ECTS-CP:**	5	**Semester**	SS

Laser Spectroscopy in Life Sciences

Laserspektroskopie in Life Sciences

Title:	Laserspektroskopie in Life Sciences
Type:	Lecture
Number:	13501
Lecturer:	Prof. Dr. Bernhard Roth
Institute:	Hanover Centre for Optical Technologies, HOT, www.hot.uni-hannover.de
Email:	bernhard.roth@hot.uni-hannover.de

Event description:

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.

Prior knowledge

Basic physics, Optical elements and measurement techniques, Lasers for spectroscopic applications, Laser interferometry, Laser spectrometry and spectroscopy, Applications of (ultra)short pulse lasers.

Recommended literature

Wolfgang Demtröder: Laser Spectroscopy 1: Basic Principles (Springer), 2008

Wolfgang Demtröder: Laser Spectroscopy 2: Experimental Techniques (Springer), 2008

Jürgen Eichler, Hans Joachim Eichler: Laser - Bauformen Strahlführung Anwendungen (Springer), 2010

Thomas Engel: Quantum Chemistry and Spectroscopy (Pearson), 2013

Additional Information

Recommended for second semester and higher (Master course)

Presence studies time:	32h	**Type of exam:**	written/ oral	**Course content**	L2/E1
Self-study:	118 h	**ECTS-CP:**	5	**Semester**	WS

Nonlinear Optics

Nichtlineare Optik

Title:	Nichtlineare Optik
Type:	Lecture
Number:	13080
Lecturer:	Prof. Dr. Detlev Ristau
Institute:	Institut für Quantenoptik, www.iqo.uni-hannover.de
Email:	faber@iqo.uni-hannover.de

Event description:

- 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

Prior knowledge

Atom and molecular physics

Recommended literature

Agrawal, *Nonlinear Fiber optics*, Academic Press
Boyd, *Nonlinear Optics*, Academic Press
Shen, *Nonlinear Optics,* Wiley-Interscience
Dmitriev, *Handbook of nonlinear crystals*, Springer
Original literature

Additional Information

Presence studies time:	42h	**Type of exam:**	written/ oral	**Course content**	L3/E1
Self-study:	108 h	**ECTS-CP:**	5	**Semester**	SS

Optical Coatings and Layers

Optische Schichten

Title:	Optische Schichten
Type:	Lecture
Number:	12140
Lecturer:	Prof. Dr. Detlev Ristau
Institute:	Institut für Quantenoptik, http://www.iqo.uni-hannover.de/
Email:	d.ristau@lzh.de

Event description:

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)

Prior knowledge

Fundamentals of optics and physics

Recommended literature

Will be announced during the course, for an introduction:

Macleod, H.A.: Thin Film Optical Filters, Fourth Edition, CRC Press 2010.

Additional Information

Three exercise sheets for homework, solution of exercises discussed during the course, major course assessment alternatively by colloquium, oral examination, or by written test

Presence studies time:	32h	**Type of exam:**	written/ oral	**Course content**	L2/E1
Self-study:	118 h	**ECTS-CP:**	4	**Semester**	WS

Optical Measurement Technology

Optische Messtechnik

Title:	Optical Measurement Technique
Type:	Lecture
Number:	32996
Lecturer:	Prof. Dr.-Ing. Eduard Reithmeier, Dr.-Ing. habil. Maik Rahlves
Institute:	Hannover Centre for Optical Technologies, HOT, www.hot.uni-hannover.de
Email:	maik.rahlves@hot.uni-hannover.de

Event description:

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.

Prior knowledge

Fundamentals of Measurement

Recommended literature

Born, Wolf: Principles of Optics;

Hecht: Optics;

Saleh, Teich: Fundamentals of Photonics;

Lauterborn, Kurz: Coherent Optics;

Goodman: Introduction to Fourier Optics;

Hugenschmidt: Lasermesstechnik;

Demtröder: Experimentalphysik

Additional Information

Presence studies time:	32h	**Type of exam:**	oral	**Course content**	L2/E1
Self-study:	118 h	**ECTS-CP:**	5	**Semester**	WS

Optical properties of micro and nanostructures

Optical properties of micro and nanostructures

Title:	Optical properties of micro and nanostructures
Type:	Lecture
Number:	--
Lecturer:	Prof. Dr.-Ing. Ludger Overmeyer, Tim Wolfer
Institute:	Institut für Transport- und Automatisierungstechnik, www.ita.uni-hannover.de
Email:	tim.wolfer@ita.uni-hannover.de

Event description:

The module teaches the basics of the optical properties of micro- and nanostructures.

After successful completion of the module, students are able to

- understand the fundamentals of geometric optics, to understand physical light / matter interactions at sub-wavelength-scale structures
- design optical grating structures
- to assess spectroscopic measurement principles and diffractive elements
- classify the production technologies of optical micro- and nanostructures
- understand the basics of photovoltaics

Contents:

- Introduction to the topic
- Fundamentals: Geometrical Optics, Calculating with complex amplitudes, Energy transfer at boundaries, Two beam interference
- Huygens´principle, Fresnel zone construction, Introduction to Fourier Optics
- Kirchhoff-Fresnel diffraction integral, Fresnel diffraction, Fraunhofer diffraction, Introduction to diffraction gratings
- Theory and applications of subwavelength gratings
- Spectroscopic gratings, Thick and thin gratings, Grating regimes
- Photonic crystals
- Imaging with diffractive optical elements
- Production technologies for micro structures with optical functions
- Photonmanagement in solar cells

Prior knowledge

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Recommended literature

Recommendation made in the lecture; lecture script

Additional Information

Presence studies time:	32h	**Type of exam:**	oral/written	**Course content**	L2/E1
Self-study:	88h	**ECTS-CP:**	4	**Semester**	WS

Optics, atomic and quantum physics (additional module)

Optik, Atomphysik und Quantenphänomene

Title:	Optik, Atomphysik und Quantenphänomene
Type:	Lecture
Number:	12454
Lecturer:	Prof. Dr. Alexander Heisterkamp
Institute:	Institut für Quantenoptik, www.iqo.uni-hannover.de
Email:	dekan@maphy.uni-hannover.de

Event description:

Topics:

- Geometrical optics
- Wavelike properties of light: Interference, refraction, polarization, birefringence
- Optics, optical instruments
- Matter waves, wave-particle dualism
- Composition of atoms
- Energy states, angular momentum, magnetic moment
- Pauli principle
- Spectroscopy, spontaneous and stimulated emission

Prior knowledge

-

Recommended literature

Born, Wolf: Principles of Optics

Saleh, Teich: Fundamentals of Photonics;

Lauterborn, Kurz: Coherent Optics

Additional Information

Additional module for students who are imposed with some or all of the following German lectures:

- Optik, Atomphysik, Quantenphänomene
- Moleküle, Kerne, Teilchen, Festkörper
- Atom- und Molekülphysik

Presence studies time:	32h	**Type of exam:**	written/ oral	**Course content**	L3/E1
Self-study:	88h	**ECTS-CP:**	-	**Semester**	WS

Photogrammetric Computer Vision

Photogrammetric Computer Vision

Title:	Photogrammetric Computer Vision
Type:	Lecture
Number:	28225
Lecturer:	Prof. Dr. Christian Heipke
Institute:	Institut für Photogrammetrie und GeoInformation, http://www.ipi.uni-hannover.de/
Email:	reich@ipi.uni-hannover.de

Event description:

After attending this 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.

Prior knowledge

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Recommended literature

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, 82.20 €, szeliski.org/Book/, see also

www.eecs.berkeley.edu/~trevor/CS280.html

http://www.cs.cmu.edu/~cil/vision.html

Additional Information

Lab work, oral exam

Presence studies time:	32h	**Type of exam:**	oral	**Course content**	L2/E1
Self-study:	118 h	**ECTS-CP:**	5	**Semester**	WS

Photonics

Photonik

Title:	Photonik
Type:	Lecture
Number:	12457
Lecturer:	Prof. Dr. Boris Chichkov, Dr. Ulf Hinze
Institute:	Institut für Quantenoptik, www.iqo.uni-hannover.de
Email:	www.iqo.uni-hannover.de

Event description:

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

Prior knowledge

Basic knowledge in coherent optics, Nonlinear Optics Lecture

Recommended literature

Saleh, Teich: Photonics, Wiley;

Maier: Plasmonics: Fundamentals and Applications, Springer;

Boyd: Nonlinear Optics, Academic Press

Additional Information

Presence studies time:	60h	**Type of exam:**	written/ oral	**Course content**	L2/E1
Self-study:	90h	**ECTS-CP:**	5	**Semester**	WS

Physics of Solar Cells

Physik der Solarzelle

Title:	Physik der Solarzelle
Type:	Lecture
Number:	13140
Lecturer:	Dr. Carsten J. Schinke, Prof. Dr.-Ing. Rolf Brendel
Institute:	Institute of Solar Energy Research Hameln (ISFH), and Department of Solar Energy, Institute of Solid-State Physics, www.isfh.de
Email:	brendel@isfh.de

Event description:

Semiconductor equations, optical properties of semiconductors, transport of electrons and holes, carrier recombination mechanisms, current-voltage curves, manufacturing process of solar cells, characterization methods for solar cells, physical limitations for efficiency improvements, new concepts.

Prior knowledge

Basic knowledge in Solid State Physics is helpful but not mandatory

Recommended literature

P. Würfel, „Physics of Solar Cells“ (WILEY-VCH Verlag GmbH & Co, 2005).

A. Goetzberger, J. Knobloch, „Crystalline Silicon Solar Cells“ (John Wiley & Sons, 1998).

Additional Information

The slides presented during the course will be available for the students.

Presence studies time:	60h	**Type of exam:**	written	**Course content**	L2/E2
Self-study:	90h	**ECTS-CP:**	6	**Semester**	SS

Production of Optoelectronic Systems

Produktion optoelektronischer Systeme

Title:	Production of Optoelectronic Systems
Type:	Lecture
Number:	--
Lecturer:	Prof. Dr.-Ing. Ludger Overmeyer
Institute:	Institut für Transport- und Automatisierungstechnik, www.ita.uni-hannover.de
Email:	Ludger.overmeyer@ita.uni-hannover.de

Event description:

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
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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

Prior knowledge

Recommended literature

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
Lecture script

Additional Information

Distinct English- and German taught lectures available

Presence studies time:	32h	**Type of exam:**	written	**Course content**	L2/E1
Self-study:	118 h	**ECTS-CP:**	5	**Semester**	WS

Proseminar Biophotonics

Proseminar Biophotonik

Title:	Proseminar Biophotonik
Type:	Proseminar
Number	12137e
Lecturer:	Dr. Merve Wollweber, Dr.-Ing. habil. Maik Rahlves, Prof. Dr. Bernhard Roth, Prof. Dr. Uwe Morgner
Institute:	Hannoversches Zentrum für Optische Technologien
Email:	bernhard.roth@hot.uni-hannover.de merve.wollweber@hot.uni-hannover.de maik.rahlves@hot.uni-hannover.de

Event description:

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.

Prior knowledge

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

Additional Information

Graded performance: oral examination and presentation slides
Type of examination: oral (marked or unmarked, as required)

Presence studies time:	30h	**Type of exam:**	seminar	**Course content**	S2
Self-study:	60h	**ECTS-CP:**	3	**Semester**	WS/SS

Proseminar Nonlinear Fiber Optics

Proseminar Nichtlinear Faseroptik: Superkontinuumserzeugung, Monsterwellen und Schwarze Löcher

Title:	Proseminar Nichtlinear Faseroptik: Superkontinuumserzeugung, Monsterwellen und Schwarze Löcher
Type:	Proseminar
Number:	12137f
Dozent:	PD Dr. Ayhan Demircan, Dr. Ihar Babushkin, Prof. Dr. Uwe Morgner
Institute:	Institut für Quantenoptik
Email:	

Event description:

Fiber-optical analogies to extremal phenomena from various fields of physics.

Prior knowledge

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Recommended literature

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Additional Information

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Presence studies time:	--	**Type of exam**	Seminar	**Course Content**	S2
Self-study:	--	**ECTS-CP:**	3	**Semester**	SS

Radar Remote Sensing

Radar Remote Sensing

Title:	Radar Remote Sensing
Type:	Lecture
Number:	28323
Lecturer:	Prof. Dr. Madhi Motagh
Institute:	Institut für Photogrammetrie und GeoInformation
Email:	

Event description:

This course is intended to provide an introduction to the technique of Interferometry Synthetic Aperture Radar (InSAR) and its application for monitoring aspects of Earth's surface including its topography and deformation. With the increasing availability of SAR systems it is becoming more crucial and important than ever to learn about these systems and to better understand what can be gained from SAR data for various types of natural disasters and engineering applications. The course covers mainly the underlying principle of InSAR measurement technique and time-series approaches of Permanent Scatterer (PS) and Small BAseline Subset (SBAS). The module will be accompanied by lab exercises that provide hands-on experience with classical processing techniques. At the end of the course the students will acquire knowledge and understanding of the fundamental concepts underlying radar remote sensing and will gain the ability to implement processing techniques to extract information from radar data. The lecture is complemented by reading and discussion of textbooks and journal papers, and a 1-day excursion to GeoForschungsZentrum (GFZ) Potsdam towards the end of the semester.

Content:

- Introduction to two-dimensional radar imaging and Synthetic Aperture Radar (SAR)
- Image resolution and SAR geometric distortions
- SAR interferometry to measure Earth's surface topography and deformation
- Airborne and space-borne SAR sensor systems
- How to access SAR data?
- Fundamental equation of Interferometry: Height ambiguity, sensitivity analysis, selection of baseline,critical baseline
- Typical processing chain: 2 and 3 pass Interferometry
- Application of radar remote sensing in geodesy, geophysics and environmental sciences
- Interferometric phase quality: Coherence
- Error sources: Residual topography; atmospheric error, phase unwrapping, decorrelation
- Time-series methods: Permanent/Persistent Scatterer Interferometry (PSI) and Small Baseline Subset (SBAS)
- Latest development in SAR systems
- Lab: Interferometry exercise using public domain software DORIS

Prior knowledge

Some familiarity with a Linuxoperating system is beneficial for lab exercises

Recommended literature

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

Additional Information

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Presence studies time:	--	**Type of exam**	Oral+Lab	**Course Content**	L1/E1/La1
Self-study:	--	**ECTS-CP:**	3	**Semester**	SS

Satellite Remote Sensing I

Fernerkundung I

Title:	Fernerkundung I
Type:	Lecture
Number:	--
Lecturer:	Dr. Christian Melsheimer
Institute:	Institut für Meteorologie und Klimatologie, www.muk.uni-hannover.de
Email:	melsheimer@uni-bremen.de

Event description

The students are learning the basics of remote sensing with emphasis on satellite meteorology, i.e. the measurement of meteorological parameters with satellites. Apart from boosting expert knowledge, the theoretical exercises also train communication skills and methodological competence.

Contents:

- Basics: Satellite orbits, electromagnetic radiation and radiative transfer
- Remote sensing with satellite instruments
- Deduction of temperature, clouds, trace gases, rainfall with remote sensing instruments of satellites
- Overview over current operative meteorological satellites and satellite instruments

Prior knowledge

Electromagnetic radiation, basics of electrical engineering, optics, nuclear physics.

Recommended literature

Kidder and Von der Haar, Satellite Meteorology: An Introduction, Academic Press

Additional information

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Presence studies time:	45h	**Type of exam:**	oral	**Course cont.**	L2/E1
Self-study:	75h	**ECTS-CP**	4	**Semester**	WS

Satellite Remote Sensing II

Fernerkundung II

Title:	Fernerkundung II
Type:	Lecture
Number:	44829
Lecturer:	Dr. Christian Melsheimer
Institute:	Institut für Meteorologie und Klimatologie, www.muk.uni-hannover.de
Email:	melsheimer@uni-bremen.de

Event description

The students are learning the basics of remote sensing of the land masses, the oceans and the atmosphere. Apart from boosting expert knowledge, the theoretical exercises also train communication skills and methodological competence.

Contents:

- Basics: Electromagnetic radiation, generation and measurement of radiation, radiative transfer
- Retrieval-methods, inverse methods
- Remote sensing (active and passive) of the land masses with visible light, infrared and microwaves
- Remote sensing (active and passive) of the oceans with visible light, infrared and microwaves
- Remote sensing (active and passive) of the atmosphere with visible light, infrared and microwaves, atmospheric probing
- Overview over important satellites and satellite instruments, current and historical

Prior knowledge

Electromagnetic radiation, basics of electrical engineering, optics, nuclear physics, satellite remote sensing I.

Recommended literature

Elachi, C. and J. van Zyl. Introduction to the physics and techniques of remote sensing. Wiley-Interscience, 2006.

Additional information

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Presence studies time:	45h	**Type of exam:**	oral	**Course cont.**	L2/ E1
Self-study:	75h	**ECTS-CP**	4	**Semester**	WS

Seminar Numerical Optics

Seminar Numerische Optik

Title:	Seminar Numerische Optik
Type:	Seminar
Number:	12076
Lecturer:	Prof. Dr. Bernhard Roth, PD Dr. Ayhan Demircan, Prof. Dr. Uwe Morgner
Institute:	Institut für Quantenoptik
Email:	

Event description:

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

Prior knowledge

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Recommended literature

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Additional Information

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Presence studies time:	--	**Type of exam**	Seminar	**Course Content**	S2
Self-study:	--	**ECTS-CP:**	3	**Semester**	SS

Seminar Theory and practice of optical functional layers

Seminar Theorie und Praxis optischer Funktionsschichten

Title:	Theorie und Praxis optischer Funktionsschichten
Type:	Seminar
Number:	--
Lecturer:	Dr. Holger Badorreck, Dr. Marco Jupé, Prof. Dr. Detlev Ristau
Institute:	Laser Zentrum Hannover e.V., www.lzh.de Institut für Quantenoptik, www.iqo.uni-hannover.de
Email:	d.ristau@lzh.de

Event description

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 simulation: kMC, MD, structure formation
- atomistic simulation: structure analysis
- non-linear excitation and laser damage

Prior knowledge

Lecture "Optical coatings"

Recommended literature

Additional information

Presence studies time:	32h	**Type of exam:**	seminar	**Course cont.**	S2
Self-study:	64h	**ECTS-CP**	3	**Semester**	SS

Solid State Lasers

Festkörperlaser

Title:	Festkörperlaser
Type:	Lecture
Number:	13083
Lecturer:	Dr. Peter Weßels, Dr. Stefan Spiekermann
Institute:	Laser Zentrum Hannover e.V:, www.lzh.de
Email:	p.wessels@lzh.de

Event description:

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

Prior knowledge

Basic knowledge in physics and coherent optics

Recommended literature

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

Additional Information

Presence studies time:	24h	**Type of exam:**	oral	**Course content**	L2
Self-study:	36h	**ECTS-CP:**	2	**Semester**	SS

Ultrashort Laser Pulses

Ultrakurze Laserpulse

Title:	Ultrakurze Laserpulse
Type:	Lecture
Number:	13082
Lecturer:	Prof. Dr. Uwe Morgner, Dr. Ihar Babushkin
Institute:	Institut für Quantenoptik,, www.iqo.uni-hannover.de
Email:	babushkin@iqo.uni-hannover.de

Event description:

Contents:

- General basics of the linear and nonlinear interaction of light and matter.
- Nonlinear propagation of short optical pulses.
- Dynamics of lasers. mode-locking in lasers.
- Types of contemporary short pulse lasers.
- Applications of ultrashort pulses in physics, chemistry and biology.
- High energy laser systems.
- Generation of high harmonics and attosecond pulses.
- Relativistic optics.

Prior knowledge

Basic knowledge in physics and coherent optics

Recommended literature

J.-C. Diels, W. Rudolph: Ultrashort Laser Pulse Phenomena, 2 Ed.(Elsevier, 2006)
A.M. Weiner: Ultrafast Optics (Wiley, 2009)
G.P. Agrawal: Nonlinear Fiber Optics 5th Ed. (Academic, 2013)
S.L. Chin: Femtosecond Laser Filamentation (Springer, 2010)
J.T. Verdeyen: Laser Electronics, 3 rd ed. (Prentice-Hall, 1995)
A. Siegman: Lasers (University Science Books, 1986)
Z. Chang, Fundamentals of Attosecond Optics, (CRC Press, 2016)

Additional Information

Presence studies time:	24h	**Type of exam:**	oral	**Course content**	L2
Self-study:	24h	**ECTS-CP:**	2	**Semester**	SS

XUV Laser Physics

XUV-Laserphysik

Title:	XUV-Laserphysik
Type:	Lecture
Number:	13088 (Lecture), 13250 (Lab)
Lecturer:	Prof. Dr. Milutin Kovacev
Institute:	Institut für Quantenoptik, www.iqo.uni-hannover.de
Email:	kovacev@iqo.uni-hannover.de

Event description:

- Introduction to coherent sources of XUV radiation
- XUV optics, detection
- XUV applications in atomic, molecular and solid-state physics

A new teaching concept will give the students the possibility to build their knowledge from hands-on projects.

Projects:

- High-power femtosecond laser systems
- Interaction of matter with strong fields
- Filamentation / plasma channels
- Absolute carrier phase
- Quantum Interference Metrology / Mode Combs
- Relativistic optics / laser particle acceleration
- Generation and detection of high harmonics
- Generation and detection of attosecond pulses
- Atomic photography
- Free-electron lasers

Prior knowledge

Basic knowledge in physics and coherent optics

Recommended literature

Z. Chang, "Fundamentals of Attosecond Optics", CRC Press 2011
D. Attwood, "Soft x-rays and extreme ultraviolet radiation", Cambridge University Press 1999
T. Brabec, "Strong Field Laser Physics", 2008 Springer
P. Jaeglé, Coherent Sources of XUV Radiation

Additional Information

--

Presence studies time:	--	**Type of exam:**	oral	**Course content**	L2/La2
Self-study:	--	**ECTS-CP:**	5	**Semester**	WS

Addresses and Contact Persons

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Office hours:
by appointment

Student association of the faculty of mechanical engineering

Student represantetives

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Internet: www.maschbau-hannover.de

AG Study information

Ivo Cichon
Michael Köhrmann
Phil Demter

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https://www.maschinenbau.uni-hannover.de/ag-studieninformation.html

Office hours:
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Examination board

Chair-man:
Prof. Dr.-Ing. B.-A. Behrens

Contact Person:
Laura Lacatena

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E-Mail: pa@maschinenbau.uni-hannover.de

Office hours:
Thu: 10^{00} – 12^{00} h

Threshold Workers Office

Chair-man:
Prof. Dr.-Ing. B.-A. Behrens

Secretary:
Laura Lacatena

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Tel. +49 (0)511 762-2271

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praktikum@maschinenbau.uni-hannover.de

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Mo: 9^{00} – 12^{00} h
Wed: 13^{00} – 16^{00} h
Thu: 14^{00} – 16^{00} h
and by appointment

Dean’s Office

Dean:
Prof. Dr.-Ing. S. Kabelac

Secretary:
Gabriele Schnaidt

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Institutes and Professors of the Faculty of Mechanical Engineering

Institute of Product Development

Prof. Dr.-Ing. R. Lachmayer

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Fax: +49 (0)511 762-4506

E-Mail: ipeg@ipeg.uni-hannover.de

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Institute for Multiphase Processes

Prof. Dr.-Ing. B. Glasmacher

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Institute of Measurement and Automatic Control

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Institute of Micro Production Technology

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Institute of Turbomachinery and Fluid Dynamics

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Institutes and Professors of the Faculty of Mathematics and Physics

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Internet: http://www.iqo.uni-hannover.de

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Internet: www.uni-hannover.de/pruefungsamt

Contact person: Arne Sindermann
E-Mail: arne.sindermann@zuv.uni-hannover.de

Office hours:
Mo – Do: 10^{00} – 12^{30} h
Do: 14^{00} – 16^{00} h

Tel.:
Mo – Do: 9^{00} – 17^{00} h
Fr: 9^{00} – 15^{00} h

Apart from office hours:
(at ServiceCenter)
Mo – Mi: 12^{30} – 17^{00} h
Do: 12^{30} – 14^{00} h and 16^{00} – 17^{00} h
Fr: 10^{00} – 15^{00} h

International Office

Wilhelm-Grunwald-Haus
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30167 Hannover

Tel: +49 (0)511 762-2548
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(Servicehotline)
Fax: +49 (0)511 762-4090

E-Mail: internationaloffice@uni-hannover.de
Internet: www.international.uni-hannover.de

Office hours:
Mo – Do: 10^{00} – 12^{00} h
Di und Do: 14^{00} – 16^{00} h

At ServiceCenter:
Mo – Do: 10^{00} – 17^{00} Uhr
Fr: 10^{00} – 15^{00} Uhr

International office:
(at ServiceCenter)

Mo - Do: $10^{00} – 13^{00}$ h

E-Mail: auslandsstudium-sc@uni-hannover.de

Advice for Foreign Students at the Service Center:

Mo: We: Th:	$11^{00} – 13^{00}$ $14^{00} – 16^{00}$ $14^{00} – 16^{00}$	Guidance and advice of foreign students, postgraduates and visiting scientist
Tu: Th:	$14^{00} – 16^{00}$ $13^{00} – 14^{00}$	Registration for Events and excuresions
Th:	$10^{00} – 13^{00}$	ERASMUS Incomings, exchange students

Matriculations Office

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30167 Hannover

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Mo – Do: $10^{00} – 17^{00}$ h
Fr: $10^{00} – 15^{00}$ h

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Office hours:
Mo – Do: $10^{00} – 17^{00}$ h
Fr: $10^{00} – 15^{00}$ h

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Fr: $9^{00} – 15^{00}$ h

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Open consultation
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Th: $14^{30} – 17^{00}$

Brief counseling (at the info desk, max. 10 minutes)
Mo – Fr: $10^{00} – 14^{00}$

Infothek (Materials for self information)
Mo – Th: $10^{00} – 17^{00}$ Uhr
Fr: $10^{00} – 15^{00}$ Uhr

Telefonische Anfragen: (Service hotline: +49 511 762 2020)
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Internet: http://www.hhi.fraunhofer.de/

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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.

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

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
Im Moore 11b
30167 Hannover
Tel.++49-511-762-2779
Fax ++49-511-762- 2763

7. CERTIFICATION

This Diploma Supplement refers to the following original documents:
Urkunde über die Verleihung des Grades vom [Date]
Prüfungszeugnis vom [Date]

Certification Date:

Chairman Examination Committee

(Official Stamp/Seal)

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 SYSTEM[1]

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.

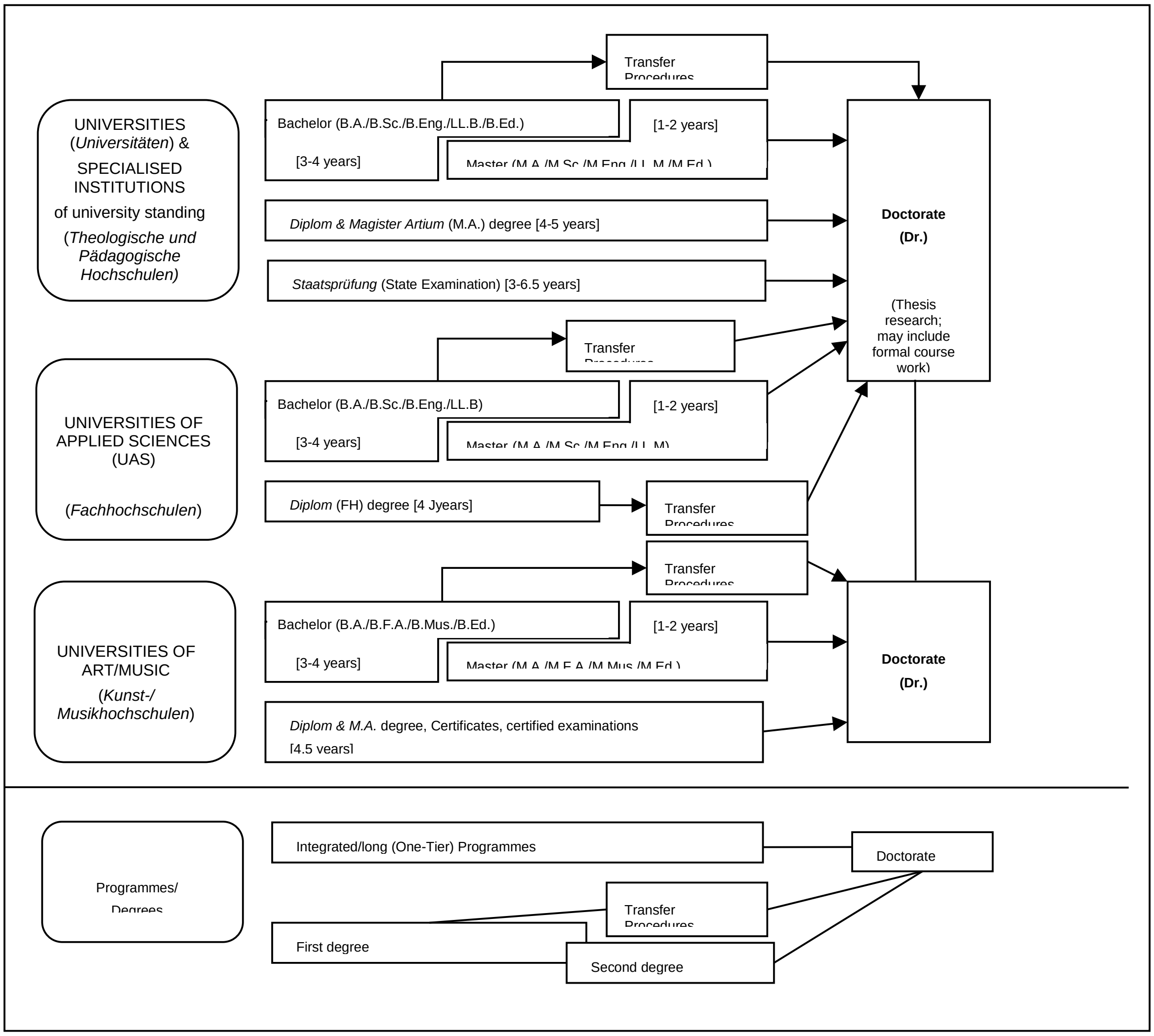
The German Qualification Framework for Higher Education Degrees[3] describes the degrees of the German Higher Education System. It contains the classification of the qualification levels as well as the resulting qualifications and competencies of the graduates.

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


Transfer Procedures
UNIVERSITIES (Universitäten) & SPECIALISED INSTITUTIONS of university standing (Theologische und Pädagogische Hochschulen)
Bachelor (B.A./B.Sc./B.Eng./LL.B./B.Ed.)
[3-4 years]
[1-2 years]
Diplom & Magister Artium (M.A.) degree [4-5 years]
Staatsprüfung (State Examination) [3-6.5 years]
Doctorate
(Dr.)
(Thesis research; may include formal course work)
Transfer
UNIVERSITIES OF APPLIED SCIENCES (UAS)
(Fachhochschulen)
Bachelor (B.A./B.Sc./B.Eng./LL.B)
[3-4 years]
[1-2 years]
Diplom (FH) degree [4 Jyears]
Transfer
Transfer
UNIVERSITIES OF ART/MUSIC
(Kunst-/ Musikhochschulen)
Bachelor (B.A./B.F.A./B.Mus./B.Ed.)
[3-4 years]
[1-2 years]
Doctorate
(Dr.)
Diplom & M.A. degree, Certificates, certified examinations
Programmes/
Integrated/long (One-Tier) Programmes
Doctorate
Transfer
First degree
Second degree