Module Handbook
Optics & Photonics (M.Sc.)
SPO 2015
Winter term 17/18
Date: 10/06/2017
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**VII Study and Examination Regulations of Karlsruhe Institute of Technology (KIT)**
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Optics & Photonics are vibrant fields of research and at the same time serve as important enabling technologies of many disciplines. Scientists and engineers are constantly pushing progress of our capabilities to generate, transmit, manipulate, detect, and utilize electromagnetic radiation (light) both on a classical and quantum level. In turn, they benefit from the availability of elaborated optical systems, advanced optical instrumentation and novel photonic devices.

One particularly prominent example is the laser. Driven by theoretical ideas in the beginning, subsequent combined efforts of scientists and engineers have resulted in one of the most versatile tools for natural sciences, industry, and consumer electronics. Applications of lasers can be found all the way from millions of low-cost laser diodes used in optical storage over selected semiconductor laser devices for long-haul data transmission to a few very-high-power lasers in nuclear fusion research.

There are many more examples for the fact that Optics & Photonics are omnipresent in modern research and application. To name just a few: light is harvested in solar cells to accommodate the ever increasing demand for energy. Light is used to monitor aerosols in the atmosphere or pollutants in industrial exhaust pipes. Advanced optical methods are indispensable for sensing in Biomedicine or in high-resolution microscopy. Researchers even manipulate the propagation of light in undreamed-of ways by artificial nano- or micro-structured materials.

As a result, scientists and engineers with a specialization in Optics & Photonics have excellent opportunities in both, industry and research institutions. They find interesting jobs in companies that design and manufacture devices and components, optical systems and instrumentation, with car suppliers, and in companies that manufacture enabling products. The field of Optics & Photonics also provides a bright prospect for start-up companies. Excellent perspectives are further given in academic and industry-near research for exploration and development of future optical methods and technologies.

The creation of the interdisciplinary master’s program in Optics & Photonics of the Karlsruhe School of Optics & Photonics (KSOP) is a direct consequence of the ever increasing need for highly qualified scientists and engineers in the fields of Photonic Materials & Devices, Advanced Spectroscopy, Biomedical Photonics, Optical Systems, and Solar Energy.
II. Studies Plan (in accordance with SPO 2015)

1. Overall Program Objectives and Qualification Targets

The ‘Master of Science in Optics & Photonics’ of Karlsruhe School of Optics & Photonics (KSOP) is an international master's program featuring a dedicated interdisciplinary education concept. The program is supported by four KIT departments (Physics, Chemistry and Bio-Science, Electrical Engineering and Information Technology, Mechanical Engineering). It further integrates several institutes of the large-scale research campus of KIT (Institute of Microstructure Technology IMT, Institute of Nanotechnology INT, Institute of Meteorology and Climate Research IMK), external research institutions (Research Center for Information Technology FZI, Center for Solar-Energy and Hydrogen Research Baden-Württemberg ZSW) as well as partners in industry into its teaching activities.

This comprehensive cooperation reflects the main intention of the program ‘Optics & Photonics’ within the frame of the KIT mission statement on teaching and learning: ‘intense scientific and research-oriented education and interdisciplinary acquisition of competences’. The goal of the program is the preparation of students in an international environment for a career in scientific institutions or in companies working in the strongly expanding area of Optics & Photonics.

To achieve this goal the curriculum comprises the following overall program objectives:

- acquisition of wide-ranging knowledge in a broad spectrum of Optics & Photonics from basic science and theory to technological applications in the introduction (1st Semester) and core-subject (2nd Semester) phases,
- research-oriented acquisition of competences in one of the interdisciplinary research areas of KSOP during the specialization phase (3rd Semester) and the master’s thesis (4th Semester),
- imparting of practical skills in scientifically oriented laboratory courses (1st and 2nd Semester) and an internship in industry or a research institution (2nd and 3rd Semester),
- acquisition of soft skills in form of integrative and additive key competencies augmented in a natural way by the inter-cultural context of KSOP.

This carefully balanced curriculum includes thorough teaching of basic knowledge, a manifold of elective topics and dedicated specialization. Students will be able to identify current and future problems in both, scientific and industrial contexts, to tackle complex tasks and to elaborate effective solutions with the use of scientific methods.
These objectives are detailed in the following qualification targets:

The graduates of the master’s program in Optics & Photonics

- have equilibrated their heterogeneous starting qualification by ‘Adjustment Courses’ in Modern Physics, Measurement and Control Systems as well as Basic Cell Biology,
- have diverse knowledge of phenomena, methods, and applications of Optics & Photonics,
- have deep insight into a specialization area / research area of KSOP,
- master concept development, mode of thought, and methods of scientific work in the context of both, natural sciences and engineering sciences,
- are able to independently solve scientific problems in Optics & Photonics using theoretical and practical/experimental methods,
- are capable to familiarize themselves with adjacent subject areas and their methods,
- have the competence to handle research- and application-oriented projects to a wide extend autonomously,
- are qualified for a doctorate program,
- are able to edit a scientific topic in a didactical way and to give a modern-media based presentation to a peer audience,
- are able to present their own scientific work in concert with the related basics in a written thesis,
- are able to assume exposed responsibility in interdisciplinary teams,
- are familiar with scientifically oriented work in an industrial environment and with business culture of German or international companies,
- are confident to live, work and communicate in a multi-cultural environment,
- have good command of the English language,
- are able to actively participate in societal forming of opinion on scientific and ecological problems.

2. Structure and Curriculum of the Master’s Program

2.a. Overview

The structure of the international master’s program on ‘Optics & Photonics’ is summarized in the below given table. The curriculum and the timetable are structured such that the M.Sc. degree can be obtained within two years. The program is subdivided into four stages: the first semester (introduction) is designed to accommodate the different backgrounds of the students entering the master’s
program with a bachelor degree in natural sciences or engineering and to provide profound background knowledge in ‘Optics & Photonics’. In the second semester the students cover a broad range of the most important topics in ‘Optics & Photonics’ (core subjects) spanning the whole range from fundamental science to technology. The students acquire in-depth knowledge in one of the interdisciplinary KSOP research areas in the third semester (specialization) and finally contribute to cutting-edge research during their master’s thesis. These four stages are complemented by the internship in industry or a research institution, which is an essential and integral part of the master’s program.

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<td>2nd Semester (Core Subjects)</td>
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<td>3rd Semester (Specialization)</td>
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The allocation of credits and the examination scheme follow the recommendations of the ECTS Users’ Guide and are in concordance with the Landeshochschulgesetz of the state of Baden-Württemberg (version of April 1st, 2015). The program has been accredited in 2014 by the internal KIT program evaluation (KIT-PLUS).
For details on the relevance of the subjects for the master’s exam see also ‘Studies and Exam Regulations’ (SPO 2015) §17. All subjects, the allocated modules and the respective courses are listed in the ‘Detailed Curriculum’ at the end of this studies plan. With help of the module code one can find the extended module description which details among others module content, learning targets as well as modality and prerequisites for the exam.

2.b. Objectives and Procedures of the Different Subjects

1st Semester (Introduction)

The introduction phase in the 1st semester comprises an Adjustment Course, compulsory modules on fundamental topics and first practical experiences in a lab course.

Adjustment Course (AdjC)

Some basic topics – modern physics, measurement and control techniques, as well as a three semester course in mathematics - are judged as compulsory prerequisites for a program in optics and photonics. Most students will have covered most of these topics during their B.Sc. studies. The first semester adjustment course (AdjC) is intended to mend the most obvious deficiencies. Due to the inhomogeneous nature of the degrees and education, an individual assignment of an adjustment course will be made for each student by the examination board. This assignment will be placed according to the students’ background.

Objectives of the Adjustment Course are:

- to provide students with a background in natural sciences fundamental knowledge in systems theory, in information acquisition and measurement, as well as in design of controllers to manipulate the system state (AdjC-MCS),
- to refresh and elaborate the knowledge in basic modern physics of students with a background in engineering sciences. The students should comprehend the fundamentals of quantum physics and their applications and how to solve physics problems by mathematical evaluation of natural laws (AdjC-MP).

The second task of the introduction phase is to provide all students with the fundamental knowledge necessary for the modules on core subjects and the specialization subject. This will be achieved by two compulsory subjects – ‘Physical Optics & Photonics’ (PhysO&P) and ‘Engineering Optics & Photonics’ (EngO&P).
Physical Optics & Photonics (PhysO&P)

‘Physical Optics & Photonics’ comprises the module ‘Fundamentals of Optics and Photonics’ (PhysO&P-FOP) with a lecture course and a problems class.

**Objectives of Physical Optics & Photonics** are:

- to refresh and elaborate the knowledge of basic laws and phenomena in optics and photonics. The students learn how to describe physical laws in a mathematical form and how to verify these laws in experiments, i.e. they acquire scientific methodology. They train to solve problems in basic and applied optics & photonics by mathematical evaluation of physics laws.

Engineering Optics & Photonics’ (EngO&P)

‘Engineering Optics & Photonics’ comprises the modules ‘Electrodynamics and Numerical Calculation of Fields’ (EngO&P-EM) and ‘Optical Engineering’ (EngO&P-OE).

**Objectives of Engineering Optics & Photonics** are:

- to understand and apply the concepts of electric & magnetic fields, of electric potential & vector potential, of wave creation and wave propagation. The student will learn the basics of numerical field calculation using appropriate software packages (EngO&P-EM),

- to learn the basic principles of optical designs and their real-world applications. The students will comprehend the human view ability and the eye system. They will be able to judge the basic qualities of an optical system by its quantitative data (EngO&P-OE).

Optics and Photonics Lab I (O&PL I)

The students will get a first hands-on experience in basic optics and measurement techniques in the ‘Optics and Photonics Lab’ (O&PL). A wide range of optical experiments have been selected from the advanced laboratory courses of the KSOP departments to amend the student’s theoretical knowledge from the fundamental courses. This subject comprises the two modules O&PL I in the winter semester and O&PL II in the summer semester.

**Objectives of Optics and Photonics Lab I and II** are:

- the students learn how to prepare and carry out experiments, analyse the obtained data as well as how to summarize and discuss their results in a scientific report.
Additive Key Competencies (AKC)

Karlsruhe School of Optics and Photonics KSOP with its international, interdisciplinary master’s and doctoral programs provides an inter-cultural environment to the students. Still, acquisition of soft skills in form of integrative and additive key competencies is an essential part of the master’s program. Modules on extra-disciplinary key competencies are provided by International Department ID (German classes: http://ksop.idschools.kit.edu/german_course.php), KIT Language Center SpZ (language courses: http://www.spz.kit.edu/index.php), Studienkolleg StK (language courses http://www.stk.kit.edu/english/german_courses.php), House of Competence HOC and Center for Cultural and General Studies ZAK (www.hoc.kit.edu, http://www.zak.kit.edu/anmeldung.php: wide spectrum of soft-skill courses, see also recommended courses in ‘Detailed Curriculum’ and module descriptions). Courses in English or the student’s native language are excluded.

2nd Semester (Core Subjects)

The core-subjects phase has the goal to provide a comprehensive education in advanced optics and photonics and simultaneously give a review on this wide and diverse field. The central part of this phase is a block of five compulsory courses which span the whole range from fundamental science to applications, from theoretical optics to materials technology and from atomistic models to optical systems.


Objectives of Advanced Optics & Photonics – Theory and Materials are:

- the students deepen their knowledge about mathematical tools in optics and photonics and learn how to apply them to the description of fundamental phenomena. They understand how to extract the physical content of a theory from its basic equations of motion by way of corresponding purposeful mathematical analyses (AO&P-TM-TO),
- the students conceive basic concepts of nonlinear-optical phenomena and understand how these effects are exploited for electro-optic and all-optical signal generation and processing. The students can apply their knowledge to the analysis and design of nonlinear-optical devices (AO&P-TM-NLO).
Advanced Optics & Photonics – Methods and Components (AO&P-MC)


Objectives of Advanced Optics & Photonics – Methods and Components are:

- the students get introduced into various methodologies of molecular spectroscopy in frequency and time domain, into the interpretation of the respective optical spectra and into their application in various fields. They gain knowledge on spectroscopic equipment and optical components for the respective spectroscopic and/or microscopic technique (AO&P-MC-SM),
- the students will comprehend the physical basis of optical communication systems enabling them to read a device’s data sheet, to make most of its properties, and to avoid hitting its limitations (AO&P-MC-OC).
- the students build knowledge on process technology for the fabrication of a range of optoelectronic devices, including LEDs, solar cells, laser diodes, photodisodes, etc. They learn to compare the advantages and disadvantages of different technological approaches, including their economic boundary conditions.

Adjustment Course - Basic Molecular Cell Biology (AdjC-BMCB)

Progress in no other field of science is so intimately linked to the continuing development and welfare of humanity as the achievements of the life sciences. Modern biomedical research, however, is inconceivable without cutting-edge Optics & Photonics technologies ranging from high-throughput sequencing to super-resolution microscopy. Most students of Optics & Photonics are therefore likely to get in contact with life scientists during their careers. Since essentially none of the students has a background in biology, the adjustment course ‘Basic Molecular Cell Biology’ (AdjC-BMCB) is compulsory for all.

Objectives of Adjustment Course - Basic Molecular Cell Biology are:

- they will prepare themselves for fruitful future collaborations with life scientists, which rely on shared concepts and terminologies. To this end, students will familiarize themselves with the basic principles and ideas of Molecular Cell Biology, which is at the heart of modern Biosciences.

The central block of modules on advanced Optics & Photonics is further complemented by the 'Optics and Photonics Lab II' (O&PL II). For a description of the objectives see 1st semester subjects.
**Internship (Int)**

This wide-spread coverage of important topics in O&P will help the students to set the course for their vocational careers following the M.Sc. - be it in a research related environment like at a university, a Fraunhofer Institute or an industrial research lab or be it in industrial development and production. This aspect is further supported by an 8-week internship in the semester break between the 2nd and 3rd semester (Int).

**Objectives of the Internship** are:

- the students shall be exposed to Optics and Photonics industry or a research institution and get involved in the solution of a concise real world problem in that domain. They gather insight in procedures and practical work in industry or research institutions. They can participate in and contribute to an interdisciplinary team and are able to present their work in discussions with others. They are able to transfer their theoretical knowledge into practical solutions to real world problems.

**3rd Semester (Specialization)**

Elective lectures from the main research areas of KSOP, an optional research project, and a seminar course on research topics in O&P are the foundation of the specialization phase in the 3rd semester.

**Specialization (SP)**

The students have to select one of the following specialization subjects:

- ‘Photonic Materials and Devices’ (Sp-PMD)
- ‘Advanced Spectroscopy’ (Sp-AS)
- ‘Biomedical Photonics’ (Sp-BMP)
- ‘Optical Systems’ (Sp-OS)
- ‘Solar Energy’ (Sp-SE).

All specialization subjects feature a dedicated interdisciplinary character with lecture courses taken from the extensive repertoire of advanced lectures of the KIT departments participating in KSOP. The lectures are complemented by an optional ‘Research Project’ (Sp-RProj) giving the students a first introduction into on-going research of one of the KSOP groups. The students have to validate a minimum of 16 CP (including optional research project) for the specialization subject.
Objectives of the Specialization Subjects are:

- the students will obtain knowledge on photonic materials starting from a microscopic description of optical material parameters via detailed discussion of inorganic and organics optical materials to nanostructures and metamaterials. They will also learn how to utilize these materials in photonic devices like lasers, LEDs, waveguides, solar cells or X-ray optics (Sp-PMD),

- the students will obtain knowledge on advanced spectroscopy starting from a microscopic description of optical properties of atoms, molecules and solids via spectroscopic instrumentation to its applications in material sciences an metrology (Sp-AS),

- the students obtain knowledge on advanced O&P methods to study biomolecules and cells, on photo-induced processes in biochemistry and on realization of light reception and vision in organisms (Sp-BMP),

- the students obtain knowledge on optical systems including generation, transmission and reception of light, realization of complex O&P systems, software engineering, or application in materials processing and metrology (Sp-OS),

- the students obtain knowledge on harvesting and conversion of solar energy, on suitable materials and device architectures as well on application and distribution of the converted energy (Sp-SE).

Seminar Course (Research Topics in O&P) (SemC)

The ‘Seminar Course’ (SemC) serves as integral module on key competencies and provides the students with a broad review on the research topics at KSOP.

Objectives of the Seminar Course (Research Topics in O&P) are:

- this common seminar on research in optics and photonics at KSOP leads to a balance between the student’s specialized profile and an indispensable broad background. Furthermore, the students will learn how to structure a scientific topic in a didactical way and how to present it to a peer audience. They will gain practical skills in modern presentation techniques.

The students have to complement their studies in the 3rd semester by 'Additional Key Competencies' (AKC). For objectives see 1st semester subjects.
4th Semester (Master's Thesis)

The master's thesis is a central element of the student’s scientific specialisation and building of an academic profile.

Master's Thesis (MThes)

An overall time of six month is allocated for the duration of the research phase, the time for writing up and for presenting the thesis in a colloquium (total 30 CP). The research towards the thesis will be performed in the group of one of the KSOP PIs or lecturers, in an industrial research lab or a research institution. The topic of the thesis has to be related to the area of optics and photonics and will be in any case assigned, supervised, and refereed by an examiner of the KSOP.

Objectives of the Master's Thesis are:

- to introduce to students in depth to scientific working methods. They learn to analyse an elaborate scientific problem, to develop suitable solutions, to achieve, evaluate and interpret experimental or theoretical results, and to summarize and discuss their work in a thesis.

The master's thesis can only be assigned by an examiner according to § 17(2-4) of the official study and examination regulations (SPO 2015). In case the master’s thesis shall be written outside of the four departments involved in KSOP the approval of the examination committee is required. The thesis is written in English language.

Preconditions for the registration of a master's thesis are regulated in § 14(1) of the SPO. The thesis can only be started when there is a maximum of two exams left to complete. The student has to complete the internship, the key competencies, the O&P labs and the seminar course before starting the master's thesis. The thesis has to be registered at latest three month after the last module examination.

For registration of the thesis the certificate of admission ('Zulassungsbescheinigung' = green form to be collected at the ‘Studierenden Service’) and a supervision agreement have to completed by the supervising examiner. The supervision agreement (original) has to be returned to the Examination Board office and a copy has to be handed in to the institute.

Six months after the starting date, the student has to hand in the master's thesis to the supervising examiner (two printed copies and an electronic version). Extension can be granted by the Examination Board upon request of the KSOP supervisor. If the thesis is not handed in within this period it will be graded with ‘nicht ausreichend’ ('failed').

The master’s thesis has to be graded within 8 weeks by the supervising examiner and a second examiner. In case there is a dissenting grading by a second examiner (according to SPO 2015 §14(7)) the final grade will be issued by the Examination Board. The topic and grade shall be marked on the green form. The supervisor
needs to hand in the green form to the ‘Studierenden Service’ and a copy to the Examination Board office.

The master’s thesis shall contain the following declaration: ‘Ich versichere wahrheitsgemäß, die Arbeit selbstständig verfasst, alle benutzten Hilfsmittel vollständig und genau angegeben und alles kenntlich gemacht zu haben, was aus Arbeiten anderer unverändert oder mit Abänderungen entnommen wurde sowie die Satzung des KIT zur Sicherung guter wissenschaftlicher Praxis in der jeweils gültigen Fassung beachtet zu haben.’ This declaration shall also be made in English in an equivalent form: ‘I herewith declare that the present thesis is original work written by me alone, that I have indicated completely and precisely all aids used as well as all citations, whether changed or unchanged, of other theses and publications, and that I have observed the KIT Statutes for Upholding Good Scientific Practice, as amended.’ For more details see also SPO 2015 §14.

3. Contact, Services, and Special Support
3.a. Gender Issues, Students with Handicaps or Chronic Illness

Special regulations apply for students in maternal or parental leave and students attending family-related obligations (SPO 2015 §12) as well as students with handicaps or chronic illness (SPO 2015 §13). Please refer to the Examination Board for assistance and for flexible adaptation of study and examination regulations.

The KSOP measures for gender equality and the contact data of the two KSOP gender commissioners can be found on the respective KSOP website (http://ksop.idschools.kit.edu/gender_equality.php).
## III. Contact

<table>
<thead>
<tr>
<th>Contact Persons</th>
<th>Contact Details</th>
<th>Address</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dr.-Ing. Judith Elsner</td>
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<td></td>
</tr>
<tr>
<td>International Department</td>
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<td></td>
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<td>Prof. Dr. Heinz Kalt</td>
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<td>Dean of Studies</td>
<td><strong>Office:</strong> +49 (0)721 608 - 43420</td>
<td>Physikhochhaus</td>
</tr>
<tr>
<td>Scientific Advisor Research</td>
<td></td>
<td>6th floor, room 6/17</td>
</tr>
<tr>
<td>Projects</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prof. Dr. Uli Lemmer</td>
<td><strong>E-Mail:</strong> <a href="mailto:uli.lemmer@kit.edu">uli.lemmer@kit.edu</a></td>
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<td><strong>Office:</strong> +49 (0)721 608 - 42531</td>
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<td>Physikhochhaus</td>
</tr>
<tr>
<td>Courses</td>
<td></td>
<td>5th floor, room 5/13</td>
</tr>
<tr>
<td>Dr. Guillaume Gomard</td>
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<td>Geb. 30.34, room 218</td>
</tr>
<tr>
<td>Courses, Mentor Ph.D. program</td>
<td></td>
<td></td>
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<tr>
<td>Miriam Sonnenbichler</td>
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<td><strong>Office:</strong> +49 (0)721 608 – 47687</td>
<td></td>
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<tr>
<td>Prof. Dr. Cornelius Neumann</td>
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<td>LTI, Engesserstraße 13, Geb. 30.34, room 221</td>
</tr>
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<td>Head of Examination Board</td>
<td><strong>Office:</strong> +49 (0)721 608 - 46052</td>
<td></td>
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<tr>
<td>Jurana Hetterich</td>
<td><strong>E-Mail:</strong> ExaminationOffice-</td>
<td>LTI, Engesserstraße 13, Geb. 30.34, room 224</td>
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<td>Office of Examination Board</td>
<td><a href="mailto:KSOP@idschools.kit.edu">KSOP@idschools.kit.edu</a></td>
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<td>Dr. Michael Hetterich</td>
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<td>Physikhochhaus</td>
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<td>Stacy Peer</td>
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<tr>
<td></td>
<td><strong>Office:</strong> +49 721 608 - 47018</td>
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more courses available from International Department ID, House of Competence HoC, Zentrum für Angewandte Kulturwissenschaften ZAK, and Sprachenzentrum SPZ

* for more information about the Modules at ZAK: www.zak.kit.edu
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<td>Advanced Lithography for Biophotonic and Optofluidic Applications - Lecture</td>
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<td><strong>Module</strong> M-PHYS-102194</td>
<td><em>Research Project</em></td>
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<td><strong>Module</strong> M-ETIT-103802</td>
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<td>* one Specialization has to be chosen, all modules within the Specialization are elective except for Sp-SolE</td>
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| Courses | Solar Energy - Lecture | V3 |
|         | Solar Energy - Problems Class | Ü1 |

| Module | M-ETIT-100475 | Plastic Electronics / Polymerelectronics | 3 | Lemmer |
| Course | Plastic Electronics - Lecture | V2 |

| Module | M-ETIT-101917 | Electric Power Generation and Power Grid | 3 | Hoferer |
| Course | Electric Power Generation and Power Grid - Lecture | V2 |

| Module | M-PHYS-102196 | Advanced Optical Materials (not offered WS 17/18) can be substituted by SP-NO Nano Optics | 6 | Wegener |
| Courses | Advanced Optical Materials - Lecture | V3 |
|         | Advanced Optical Materials - Problems Class | Ü1 |

| Module | M-PHYS-102408 | Solid-State Optics, without Exercises | 6 | Hetterich |
| Course | Solid-State Optics - Lecture | V4 |

| Module | M-ETIT-101914 | Laser Materials Processing (no offered WS 17/18) | 3 | Graf |
| Course | Laser Materials Processing - Lecture and Problems Class | block course |

| Module | M-MACH-101924 | Solar Thermal Energy Systems | 3 | Dagan |
| Course | Solar Thermal Energy Systems - Lecture | V2 |

| Module | M-PHYS-103089 | Computational Photonics, without ext. Exercises (not offered WS 17/18) | 4 | Rockstuhl |
| Courses | Computational Photonics - Lecture | V2 |
|         | Computational Photonics - Problems Class | Ü1 |

<p>| Module | M-PHYS-102194 | Research Project | 4 | Kalt |
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04.10.2017

Optics & Photonics (M.Sc.)
Module Handbook, Date 10/06/2017, Winter term 17/18
Lab Descriptions

Optics and Photonics Lab I + II

Lecturers:

PD Dr. Michael Hetterich, Dr. Christoph Sürgers  
(Department of Physics)

habil. Andreas Unterreiner, Dr. Franco Weth  
(Department of Chemistry and Biosciences)

Dr.-Ing. Klaus Trampert  
(Department of Electrical Engineering and Information Technology)

Uwe Hollenbach, Dr. Martin Lauer  
(Department of Mechanical Engineering)

Content and organisation:

This laboratory course comprises a series of optical experiments selected from the advanced laboratory courses of the Departments of Physics, Electrical Engineering and Information Technology as well as Mechanical Engineering. The students will amend their theoretical knowledge from the fundamental courses by exploring, e.g., light emitters, high-resolution spectroscopy, interferometers, fiber optics or solar cells. Depending on the usual time required to complete one lab, they award lab units (one lab unit should correspond roughly to ½ day’s work). Students have to collect 15 lab units in total over the course of two semesters, of which at least 3 lab units from the Department of Physics and at least 5 lab units from the Department of Electrical Engineering must be chosen. The labs will be marked with +/-0-. In case of “-”, the lab units do not count. The choice of labs must be made at the beginning of the first semester, so that the students can be registered with the respective department’s labs (mail to: carolin.klusmann@kit.edu). Upon completion of the whole course, the O&P lab will award 10 credit points (5 per semester).

Topics and lab objectives:

1. Optical tweezers (Department of Physics) (2 lab units)
The principle of optical tweezers is demonstrated, and the maximum trapping force realized by the focused laser is evaluated. To this end, the possible transport speed of small polystyrene beads and their Brownian motion are measured.

2. **Fluorescence correlation spectroscopy (fcs) (Department of Physics) (2 lab units)**

In this lab course you learn the basic principles of a modern confocal laser scanning microscope with ultra-sensible light detection. Properties of single fluorescent nanoparticles and molecules in normal conditions and in aqueous solutions are investigated using the method of fluorescence correlation spectroscopy. This method allows one to determine the concentration and the size of particles in the nanometer range with a very high precision.

3. **Quantum eraser (Department of Physics) (2 lab units)**

A classically explicable analogue to the quantum eraser is demonstrated using a Mach–Zehnder interferometer. Students will learn to set up the interferometer and observe the dis- and reappearance of (quantum) interferences for certain combinations of light polarization.

4. **Semiconductor spectroscopy (Department of Physics) (2 lab units)**

By polarization-dependent measurements of absorption and transmission spectra of several two- and three-dimensional semiconductor structures it is possible to extract information about the properties of semiconductors, e.g., excitons, energy gap, dimensions, refractive index.

5. **Diffusive invisibility cloak (Department of Physics) (2 lab units)**

The principle of invisibility cloaking is demonstrated in general and diffusive light cloaking is observed in detail. To get the idea of diffusive light cloaking, several experiments on light scattering materials will be performed and the difference between ballistic and diffuse transmitted light will be pointed out.

6. **Laser resonator (Department of Physics) (2 lab units)**

This lab provides an introduction into optical lab work, e.g., the use of optical components is introduced. In particular, a titanium:sapphire laser is adjusted to make it lase, different spectra are taken, and the use / application of the laser is worked out.

7. **Magneto-optical Kerr effect – MOKE (Department of Physics) (2 lab units)**

Measurement of the magnetization of thin films and heterostructures by the MOKE is of great importance for magneto-optical data storage. Polarization and refraction of light, the Kerr effect and magnetism are the key terms of this course.
8. **Zeeman effect (Department of Physics) (2 lab units)**

The Zeeman effect of helium atoms is measured with a grating spectrograph. Fundamental aspects of atomic physics are examined in this course, e.g., selection rules, $g$-factor, atom–light interaction, magnetic quantum number.

9. **Fabry–Pérot interferometer (Department of Physics) (2 lab units)**

A Fabry–Pérot interferometer allows the determination of optical spectra with very high resolution. The hyperfine structure spectrum of $^{205}\text{Tl}$ is measured with high accuracy considering the dispersion of the spectrometer.

10. **Optoelectronics laboratory (Department of Electrical Engineering and Information Technology) (8 lab units | Series of four labs)**

   a. Transmission measurement: This laboratory will deal with the measurement of Transmission and reflection of optical filters. You learn how to measure optical densities.

   b. Characterization of an organic laser: The laboratory is concerning with the theoretical basics and experimental techniques of optical pumped organic lasers. A laser safety instruction is required.

   c. Compact fluorescent lamps: Compact fluorescent lamps are operated on an electronic gear (ballast). Properties of the lamp as well as those of the ECG are measured, i.e., real and reactive power as functions of the line voltage, luminous flux, dependent on system power, rms, lamp current and line voltage etc.

   Spectroscopy and optical sensor technologies: The monochromator is the basic tool for optical metrology. With a practical experiment the lab should give an overview of the physical principles and main properties of this instrument. The topics higher orders, optical limitation, diffraction, etc. will be discussed and shown with a simple and open monochromator and Xe-arc lamp. The experiment also shows the efforts and drawbacks of the most-used optical sensors, the Si-diode and multi-alkali photomultiplier.

11. **Nanotechnology laboratory (Department of Electrical Engineering and Information Technology) (8 lab units | Series of four labs)**

   d. E-beam: Electron-beam microscopy and electron-beam lithography (EBL) are standard methods for the analysis and fabrication in micro- and nanotechnology. The laboratory gives a practical introduction how electron-beam microscopy works, where the benefits and limitations are. Also experience of building own nanostructures by electron-beam lithography are given.

   e. OLED fabrication: The market of organic light-emitting diodes (OLEDs) has attracted a lot of attention over the last couple of years due to the potential for low cost, light weight and flexible devices. In this practical course we examine the properties of polymer OLEDs that are to be prepared in a clean room
environment beforehand. The trainees become familiar with all fabrication steps of solution-processed OLEDs and a typical characterization of organic devices.

f. Interference lithography: Interference lithography is a production method for periodic nanostructures. It is possible to structure large areas with one- or two-dimensional gratings. In this experiment, the students create a one-dimensional grating with a lattice constant of 400 nm. Afterwards they transfer this grating into a silicon substrate using RIE (reactive ion etching). The aim of this experiment is an advanced comprehension of the potentials and problems of nanostructuring. A laser safety instruction is required.

g. Photolithography: This experiment introduces students to the methods that are used for the fabrication of microstructures. Each student fabricates his/her own structure using standard photolithography and another one using a lift-off process. During the experiment, students get to know basic clean room techniques such as spin coating, exposure and development of photoresist layers, evaporation of metal in a vacuum chamber and etching through a photoresist mask. This is a series of four labs. Since most labs will take place in the clean room facilities, a proper clean room introduction is a mandatory part of this course.

12. Lighting Technology lab (Department of Electrical Engineering and Information Technology) (8 lab units | Series of four labs)

h. Far-field goniometer lab (Eulumdat): In this experiment you work with the biggest test device in the Light Technology Institute. You measure the angle resolved light intensity (cd) distribution of a normal luminaire. The test device is two floors high and could measure luminaires up to 2m and a weight of 50kg.

i. Near-field goniometer lab (Ray files): In this experiment you measure the full angle resolved information of an LED. These data is the input for CAD simulation of non-imaging optics as used in general lighting applications today. This data set is afterwards used in the experiment “simulation of optical systems”.

j. Thermal influence on the spectrum of an LED: As known LEDs are the light sources in future for all lighting application. So it is good to know how LED behaves on the most important parameter, the temperature. Simulation of optical systems: In this experiment you get a first contact to most common used optical simulation tool “light-tools” which base on raytracing. In the tutorial you build your own flashlight in the virtual reality.

13. Solar-Energy laboratory (Department of Electrical Engineering and Information Technology) (8 lab units | Series of four labs)

k. Fabrication and Characterization of Organic Solar Cells: In this experiment you fabricate an organic solar cell by yourself in the cleanroom. You will prepare the substrate, structuring the anode, spin coating of the polymers and evaporating the metal cathode. Afterwards you will measure the U-I-Curve of the build organic-solar-cell and determine the optical efficiency.
I. Modelling of Organic Solar Cells: Here you simulate the electrical behavior of an organic-solar-cell and characterize the typical behavior.

m. Quantum efficiency measurements of solar cells: In this experiment you try to determine the quantum efficiency of a Si-Cell with a measurement at lab conditions.
Outdoor measurements of photovoltaic modules: In this experiment you learn the difference between measurements under lab conditions and the behavior under realistic conditions. I hope for you that the sun will shine!

14. Backscattering in optical fibers (Department of Electrical Engineering and Information Technology) (2 lab units)

This module gives an introduction to optical time-domain reflectometry. This scheme monitors fiber-optical links for changes in transmission quality or locations of damages to the fiber by evaluating backscattered signals. It is an important routine employed by all major telecommunication companies to check the integrity of optical links.

15. Ring resonator filters (Department of Electrical Engineering and Information Technology) (2 lab units)

Ring resonator waveguide structures are useful for adding or dropping information in networks switches. Their principle of operation is investigated with a microwave-frequency plug-and-play model (10 GHz). Transmission and filtering properties are then experimentally verified with a network analyzer. Finally, finite-element-simulations are performed for visualization and a cross-check with theory.

16. Laser diodes and LEDs (Department of Electrical Engineering and Information Technology) (2 lab units)

Highest-data-rate laser diodes and efficient LEDs are key components in optical communications engineering. This experiment gives insights into the optical and electronic properties of laser diodes and LEDs.

17. Optical detectors (Department of Electrical Engineering and Information Technology, 2 lab units)

Semiconductor photodiodes of various types are evaluated for their effectivity in detecting weak light pulses at optical communication wavelengths (800 nm to 1550 nm). They are important for error-free conversion of optical data back into the electrical domain.

18. Optics Design Lab (Department of Electrical Engineering and Information Technology) (5 lab units):

This lab is done at five consecutive afternoons. During this course the students will learn the use of the optical design tool Zemax. It is strongly recommended to attend
the lecture “Optical Engineering” before or during this lab course. The course comprises the following exercises:

- Simulation of simple optical systems (glasses, magnifying-glass, microscope, binoculars, telescope)
- Aberrations (spherical, chromatic, astigmatism)
- Evaluation of picture quality of optical systems (aberrations, PSF, MTF)
- Computer-aided optimization of complex optical systems (system optimization, tolerancing)

19. Optical Waveguides (Department of Mechanical Engineering, Institute of Microstructure Technology, Campus North) (2 lab units)

The following lab of the Photonic Systems group is offered by the Institute of Microstructure Technology (IMT) at the Karlsruhe Institute of Technology (KIT). In addition to the very interesting lab itself, the student will have the opportunity to gain some insight into this large facility. Transport is possible via the KIT shuttle bus, but must be organized by the students themselves. In the lab course the students will be trained in the characterization of planar structured optical waveguides and circuits manufactured in polymers at IMT by photolithographic processing. After a short oral introduction the students will be trained in different measurements techniques:

n. optical fiber preparation and splice technique (used for fiber butt coupling to planar stripe waveguides and to build small fiber networks in the measurement set-ups)

o. m-line spectroscopy (measurement of the effective mode indices for different wavelengths, demonstration of IWK calculation method, defining the refractive index profile, the maximum index contrast and the decay constant depending on UV exposure)

p. near-field intensity distribution (NFP) measurement (discussion of the mode order and mode field diameter of single mode waveguide structures)

q. far-field intensity distribution (FFP) measurement (discussion of the far-field symmetry, the divergence angle and the calculation of numerical aperture (NA))

r. waveguide insertion loss (discussion of the different loss parts: coupling loss, mode field mismatch, mismatch of NA, structure loss, material loss) polarization analysis (measurement of the polarization ellipse parameter and demonstration of the polarization-dependent loss calculation)

20. Hyperspectral Imaging (Department of Mechanical Engineering, Institute of Microstructure Technology, Campus North, 3 lab units)

In this lab students will learn about hyperspectral imaging by a hands-on approach in which they will use a bespoke set-up and learn the fundamentals of hyperspectral imaging, work with optical components, learn the structure of the set-up, how to align the system, perform measurements, perform data acquisition and data analysis. At the end of the lab, the student should be able to distinguish a fake leaf from a real leaf by means of hyperspectral imaging.
21. Mobile robot platform / machine vision (offered only in winter term)  
(Department of Mechanical Engineering, MRT) (2 lab units)

To perform a specified task autonomously is a crucial part in many robotics applications and requires the interaction between different algorithms. Especially in dynamic environments, the perception of the vicinity of the robot is important to handle unforeseen situations. In recent years, the perception part is usually done using cameras which offer rich information about the environment. The course offers the opportunity to apply computer vision and control algorithms using an autonomous vehicle. It specifically addresses object recognition, collision avoidance and vehicle control.

22. Femtosecond spectroscopy in solution (offered only in summer term)  
(Dep. of Chemistry) (2 lab units)

The aim of this lab course is to provide the necessary basics to perform ultrafast spectroscopy experiments in the visible and near-infrared region with laser pulses of about 20 femtosecond duration. A home-built Ti:sapphire femtosecond oscillator will be set up and used. Laser pulses will be characterized by determining the time-bandwidth product and/or recording the impulsive rise in the transient response of a dye molecule after absorption and photo-excitation to its electronically excited state. Femtosecond laser pulses will then be used to investigate the photo-dynamics of the dye molecule DTTCI in a polar solvent by recording its time-resolved response after photo-absorption.

23. Infrared multi-pass cell (Department of Chemistry, 3 lab units)  
 currently not available

The students will be setting up a multi-pass cell (based on the principle of a Herriot cavity) from scratch in a table-top experiment with the particular aim of using it in the mid-infrared spectral region (with wavelengths of 4.5–12 µm). The goal is to get the students acquainted with the concept of cavity and the geometrical optics of a resonator ("stability conditions") which will also be deepened by a few exercises and calculations. In the course of characterizing the cell the students are working with different types of detectors (photodiodes and pyroelectric probe heads) and beam profilers as well as with a pulsed infrared laser light source. Spectral characterization includes the usage of a Fizeau type interferometer. As a first application the students will take an infrared absorption spectrum of a diluted gas.

24. Vibrational Raman spectroscopy (Department of Chemistry, 2 lab units)

In this lab course, the students will take vibrational Raman spectra of several condensed phase samples using a commercial fiber-coupled Raman spectrometer. Learning the basics of resonant and non-resonant Raman scattering (e.g., selection rules, Raman vs. IR active modes) in molecular spectroscopy is one of the major goals as well as important applications like efficient Rayleigh line filtering, data evaluation (Stokes and anti-Stokes shift, evaluation of force constants), vibrational
isotope effects (e.g., in C6H6 vs C6D6). Another focus is on the interpretation of vibrational Raman spectra.

25. Biological fluorescence microscopy (Institute of Zoology, Department of Cell- and Neurobiology) (3 lab units)

The lab includes a first introduction to the application of fluorescence microscopy in the biosciences. Pre-processed specimens from our current research projects will be provided and imaged using cutting-edge research microscopes by the participants. Acquired images will be processes and interpreted.

26. Optical Coherence Tomography (Institute of Biomedical Engineering, Department of Electrical Engineering and Information Technology, 2 lab units)

This lab course introduces students to the concept of Fourier Domain Optical Coherence Tomography (FDOCT). Students will learn about the setup of a laboratory FDOCT, and will have hands-on experience of adjusting the reference arm path-length of a Michelson interferometer. Later students will examine how the bandwidth of the superluminescent diode (SLD) affect the axial resolution of OCT. Dispersion compensation and the Fourier Transform of the interference spectrum will also be addressed. For this course, laser safety instruction is required.

General Information

Preparation:

Prerequisites vary from experiment to experiment. Indispensable is a basic knowledge of optics. Some experience in semiconductors is favorable for some of the experiments. Students have to prepare for each experiment by impropriating the required knowledge afore by means of preparation material.

Procedure:

The main focus of this course is on laboratory work. Before starting the experiments, the students are questioned about the underlying theories in a short interview. Students have to generate an experiment report/data interpretation of their measurements.

Performance Appraisal:

| Interview | 33 % |
Course material:

For each experiment there is a short description of the experiment itself, the exercises that have to be handled and a detailed description of the underlying theories. This material will be handed out about one week prior to the lab by the respective lab supervisor.

Literature:

To supplement the preparation material, students are expected to access the library.

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Institute of Biomedical Engineering

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E-Mail: yilun.su@kit.edu
Part VI

Modules

1 Master Thesis

Module: Module Master’s Thesis  [M-ETIT-102362]

Responsibility: Cornelius Neumann
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory
Contained in: Master Thesis

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Compulsory

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Learning Control / Examinations

written thesis and oral presentation (final talk)

Conditions

Preconditions for the registration of a master’s thesis are regulated in § 14(1) of the SPO. The thesis can only be started when there is a maximum of two exams left to complete. The student has to complete the internship, the key competencies, the O&P labs and the seminar course before starting the master’s thesis. The research towards the thesis will be performed in the group of one of the KSOP PIs or lecturers, in an industrial research lab or a research institution. The topic of the thesis has to be related to the area of optics and photonics and will be in any case assigned, supervised, and refereed by an examiner of the KSOP.

Qualification Objectives

Objective of the Master’s Thesis is to introduce to students in depth to scientific working methods. They learn to analyse an elaborate scientific problem, to develop suitable solutions, to achieve, evaluate and interpret experimental or theoretical results, and to summarize and discuss their work in a thesis.

Workload

900 h including writing of thesis and preparation and presentation of final talk
2  Internship

Module: Internship  [M-ETIT-102360]

Responsibility:  Ulrich Lemmer, Christoph Stiller

Organisation:  KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage:  Compulsory
Contained in:  Internship

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Learning Control / Examinations

1. Internship confirmation/certificate from industry or research institute.
   The internship confirmation is issued directly by the company or institute, respectively. The confirmation should be signed by the local supervisor and contain the following information (1) the student’s name, birthday and matriculation number, (2) start and end date of the internship (minimum eight weeks without vacations), (3) the title of the project, and (4) company(institute, sector and supervisor.

2. Delivery of a written report on methodology and results (ca 10 pages).
   The internship report comprises a written report and evaluation to be handed in to the responsible KSOP examiner.

3. Presentation
   In the internship presentation the students have to present the project work of their internships to their peers followed by a discussion of the results.
   The presentation of the internship report is scheduled in November. The exact date will be announced.

Qualification Objectives
The students shall be exposed to Optics and Photonics industry or a research institution and get involved in the solution of a concise real world problem in that domain. They gather insight in procedures and practical work in industry or research institutions. They acquire hands-on experience in a concise practical task in Optics and Photonics. They can participate in and contribute to an interdisciplinary team and are able to present their work in discussions with others. They are able to transfer their theoretical knowledge into practical solutions to real world problems. The students

• understand work procedures and methodology in industrial or a research institution.
• understand requirements in an industrial or research environment.
• understand the interrelation of theoretical findings, simulations, experimental studies and practical solutions in Optics and Photonics.
• are able to systematically approach a practical problem.
• gather experience in interdisciplinary team work and are able to express their knowledge in such an environment.
• are able to scientifically report and present their work.

Content
A typical internship shall include
I. Problem formulation
II. State-of-the-art from literature in the field
III. Introduction to experimental platform
IV. Design and experiments  
V. Validation and evaluation of experiments  

Recommendations  
Scientific background in Optics and Photonics  

Literature  
Individual literature will be provided by the external internship advisor  

Workload  
total 360 h including 8-week (320 h) project work in industry plus 40 h of report writing and presentation of results
3 Engineering Optics & Photonics

Module: Electromagnetics and Numerical Calculation of Fields  [M-ETIT-100386]

Responsibility: Olaf Dössel
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Engineering Optics & Photonics

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Learning Control / Examinations
Type of Examination: written exam
Duration: 120 Minutes
Modality of Exam: The written exam is scheduled for the beginning of the break after the WS.

Conditions
One exercise sheet is handed out to the students as homework fortnightly. Solutions of the problems are submitted voluntary.
Submission in groups of 2 students is possible. Participation in the exercises is recommended to qualify for the written exam.

Qualification Objectives
Students with very different background in electromagnetic field theory will be brought to a high level of comprehension. They will understand the concept of electric & magnetic fields and of electric potential & vector potential and they will be able to solve simple problems of electric & magnetic fields using mathematics. They will understand the equations and solutions of wave creation and wave propagation. Finally the student will have learnt the basics of numerical field calculation and be able to use software packages of numerical field calculation in a comprehensive and critical way.

The student will
- be able to deal with all quantities of electromagnetic field theory (E, D, B, H, J, M, P, ...), in particular: how to calculate and how to measure them,
- derive various equations from the Maxwell equations to solve simple field problems (electrostatics, magnetostatics, steady currents, electromagnetics),
- be able to deal with the concept of field energy density and solve practical problems using it (coefficients of capacitance and coefficients of inductance),
- be able to derive and use the wave equation, in particular: to solve problems how to create a wave and calculate solutions of wave propagation through various media,
- be able to outline the concepts, the main application areas and the limitations of methods of numerical field calculation (FDM, FDTD, FIM, FEM, BEM, MoM, TLM)
- be able to use one exemplary software package of numerical field calculation and solve simple practical problems with it.

Content
This course first gives a comprehensive recap of Maxwell equations and important equations of electromagnetic field theory. In the second part the most important methods of numerical field calculation are introduced. Maxwell’s equations, materials equations, boundary conditions, fields in ferroelectric and ferromagnetic materials...
electric potentials, electric dipole, Coulomb integral, Laplace and Poisson’s equation, separation of variables in cartesian, cylindrical and spherical coordinates
Dirichlet Problem, Neumann Problem, Greens function, Field energy density and Poynting vector, electrostatic field energy, coefficients of capacitance vector potential, Coulomb gauge, Biot-Savart-law magnetic field energy, coefficients of inductance magnetic flux and coefficients of mutual inductance, fields problems in steady electric currents,
law of induction, displacement current
general wave equation for E and H, Helmholtz equation
skin effect, penetration depth, eddy currents
retarded potentials, Coulomb integral with retarded potentials
wave equation for $\varphi$ and A, Lorentz gauge, plane waves
Hertzian dipole, near field solution, far field solution
transmission lines, fields in coaxial transmission lines
waveguides, TM-waves, TE-waves
finite difference method FDM
finite difference - time domain FDTD, Yee’s algorithm
finite difference - frequency domain
finite integration method FIM
finite element method FEM
boundary element method BEM
solving large systems of linear equations
basic rules for good numerical field calculation
The lecturer reserves the right to alter the contents of the course without prior notification.

Literature
Matthew Sadiku (2001), Numerical Techniques in Electromagnetics. CRC Press, Boca Raton, 0-8493-1395-3

Workload
total 120 h, hereof 45h contact hours (30h lecture, 15h problem class), and 75h homework and self-studies
**Module: Optical Engineering  [M-ETIT-100456]**

**Responsibility:** Wilhelm Stork  
**Organisation:** KIT-Fakultät für Elektrotechnik und Informationstechnik  
**Curricular Anchorage:** Compulsory Elective  
**Contained in:** Engineering Optics & Photonics

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**Identifier** | **Course** | **ECTS** | **Responsibility**  
T-ETIT-100676 | Optical Engineering | 4 | Wilhelm Stork

**Learning Control / Examinations**
Type of Examination: Oral exam  
Duration of Examination: ~30 Minutes  
Modality of Exam: The oral examinations are scheduled after the lecture term. Please contact Professor Stork for an appointment. This examination can be combined with an exam of Optical Design Lab.

**Conditions**
There are no prerequisites for participation at this examination.

**Qualification Objectives**
The students from different backgrounds refresh and elaborate their knowledge of engineering optics and photonics. They will get to know the basic principles of optical designs. They will connect these principles with real-world applications and learn about their problems and how to solve them. The students will know about the human view ability and the eye system. After the module they will be able to judge the basic qualities of an optical system by its quantitative data. After the course, students will:

- understand fundamental optical phenomena and apply it to solve optical engineering problems;
- work with the basic tools of optical engineering, i.e. ray-tracing by abcd-matrices;
- get a broad knowledge on real-world applications of optical engineering;
- learn about the potential of optical design for industrial, medical and day-to-day applications;
- know up-to-date optical engineering problems and its solutions.

**3.0.1 Content**
The course “Optical Engineering” teaches the practical aspects of designing optical components and instruments such as lenses, microscopes, optical sensors and measurement systems, and optical disc systems (e.g. CD, DVD, HVD). The course explains the layout of modern optical systems and gives an overview over available technology, materials, costs, design methods, as well as optical design software. The lectures will be given in the form of presentations and accompanied by individual and group exercises. The topics of the lectures include:

I. Introduction (Optical Phenomena)  
II. Ray Optics (thin/thick lenses, principal planes, ABCD-matrices, chief rays, examples: Eye, IOL)  
III. Popular Applications (Magnifying glass, microscope, telescope, Time-of-flight)  
IV. Wave Optics (Interference, Diffraction, Spectrometers, LDV)  
V. Aberrations I (Coma, defocus, astigmatism, spherical aberration)  
VI. Fourier Optics (Periodical patterns, FFT spectrum, airy-patterns)  
VII. Aberration II (Seidel and Zernike Aberrations, MTF, PSF, Example: Eye)  
VIII. Fourier Optics II (Kirchhoff + Fresnel, contrast, example: Hubble-telescope)
IX. Diffractive Optics Applications (Gratings, holography, IOL, CD/DVD/Blu-Ray-Player)
X. Interference (Coherence, OCT)
XI. Filters and Mirrors (Filters, antireflection, polarization, micro mirrors, DLPs)
XII. Laser and Laser Safety (Laser principle, laser types, laser safety aspects)
XIII. Displays (Pico projectors, LCD, LED, OLED, properties of displays)

Recommendations
Solid mathematical background

Literature
E. Hecht: Optics
J.W. Goodmann: Introduction to Fourier optics
K.K. Sharma: Optics - Principles and Applications

Workload
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and selfstudies
4 Physical Optics & Photonics

Module: Fundamentals of Optics and Photonics [M-PHYS-101927]

Responsibility: David Hunger
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective
Contained in: Physical Optics & Photonics

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Learning Control / Examinations
Type of Examination: written exam
Duration of Examination: 120 Minutes
Modality of Exam: The written exam is scheduled for the beginning of the break after the WS. A resit exam is offered at the end of the break. A test exam is offered before the Christmas holidays.

Conditions
One exercise sheet is handed out to the students as homework each week. Solutions of the problems have to be submitted within one week. Submission in groups of two students is possible. An overall amount of 40% of the problems given in the exercises (the test exam is counted equivalent to an exercise sheet) have to be solved correctly. Additionally, active participation in the problems classes (two times presentation of solutions on blackboard in class) is required to qualify for the written exam.

Qualification Objectives
The students from different backgrounds refresh and elaborate their knowledge of basic optics and photonics. They comprehend the physics of optical phenomena and their application in simple optical components. They learn how to describe physical laws in a mathematical form and how to verify these laws in experiments, i.e. they acquire scientific methodology. They train to solve problems in basic and applied optics & photonics by mathematical evaluation of physical laws.

The students
- can derive the description of basic optical phenomena from the ray, wave or particle properties of light
- know how to calculate ray paths using matrix optics and how to apply the laws of beam optics
- understand the implications of anisotropic media to the polarization of light and related device application
- comprehend the concepts of coherence, interference and diffraction and are aware of their importance in optics and photonics
- are able to design and evaluate the performance of interference/diffraction based optical devices like interferometers, optical coatings, spectrometers and holograms
- know how to apply mathematical concepts like correlation functions and Fourier transformation to the solution of optical problems
- are familiar with basic microscopic models of light-matter interaction and are able to apply these concepts to describe phenomena like light propagation, frequency-dependence of optical constants, absorption and emission
- conceive the operation principle of various types of lasers
- have a good visualization of numerous optical phenomena acquired from the demonstration experiments
- they understand how scientific research advances by the interplay of experimental findings, phenomenological description and mathematical treatment
Content
I. Introduction (Ray Optics; Wave Optics; Photons)
II. Beam Optics (Gaussian Modes; Effect of Optical Components on Gaussian Beams)
III. Polarization and Optical Anisotropy (Polarization, Jones Vectors and Matrices; Birefringence and its Applications; Optical Activity; Induced Anisotropy and Modulators)
IV. Coherence, Interference and Diffraction (Spatial and Temporal Coherence, Fourier Transformation, Correlation Functions, Interference; Interferometer; Fourier Spectroscopy; Multi-Beam Interference, Fabry-Perot, Dielectric and Bragg Mirrors; Diffraction at Slit, Aperture and Grating; Fresnel and Fraunhofer Diffraction; Fourier Optics; Diffraction-Limited Resolution; Spectrometer; Diffractive Optics, Holography)
V. Light and Matter (Lorentz Oscillator Model, Dielectric Function, Polariton Propagation; Kramers-Kronig Relations; Two-Level Systems, Einstein Coefficients, Fermi’s Golden Rule)
VI. Laser: Basic Principles (Components of a Laser, Types of Lasers; Short-Pulse Generation)

Recommendations
Solid mathematical background, basic knowledge in physics

Literature
D. Meschede: Optics, Light and Lasers
B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics
F.G. Smith, T.A. King and D. Wilkins: Optics and Photonics, An Introduction

Workload
Total 240 h, hereof 90h contact hours (60h lecture, 30h problem class), and 150h homework and self-studies
Advanced Optics & Photonics – Theory and Materials

Module: Theoretical Optics (4) [M-PHYS-102280]

Responsibility: Carsten Rockstuhl
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory
Contained in: Advanced Optics & Photonics – Theory and Materials

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Identification / Examinations
Type of Examination: written exam
Duration of Examination: 120 Minutes
Modality of Exam: The written exam is scheduled for the beginning of the break after the SS. A resit exam is offered at the end of the break. A test exam is given in mid June.

Conditions
One problems sheet is handed out to the students as homework each week. Solutions of the problems have to be submitted at the beginning of the subsequent tutorial. An overall amount of 50% of the problems given in the exercises and the test exam (the test exam is counted equivalent to three problems sheets) have to be solved correctly.

Qualification Objectives
The students deepen their knowledge about the theory and the mathematical tools in optics and photonics. They learn how to apply these tools to describe fundamental phenomena and how to predict observable quantities that reflect the actual physics from the theory by way of a corresponding purposeful mathematical analyses. They learn how to solve problems of both, interpretative and predictive nature with regards to model systems and real life situations.
The students
- understand the theoretical basis and physical content of the classical Maxwell equations and the quantum description of light
- know how to formulate and discuss optical properties in mathematical form
- are able to utilize advanced mathematical tools for the quantitative description of wave propagation in various settings such as anisotropic materials and diffractive systems
- are able to quantify and utilize basic phenomena of coherence
- are familiar with the quantitative analysis of classical wave propagation in basic devices and systems
- appreciate the limitations of the classical description of light and the novel phenomena associated with systems for which a quantum description is required
- are able to quantitatively analyse simple quantum optical devices

Content
- Review of Electromagnetism (Maxwell’s Equations, Stress Tensor, Material Properties, Kramers-Kronig Relation, Wave Propagation, Poynting’s Theorem)
- Crystal Optics (Polarization, Anisotropic Media, Fresnel Equation, Applications)
- Classical Coherence Theory (Elementary Coherence Phenomena, Theory of Stochastic Processes, Correlation Functions)
- Quantum Optics and Quantum Optical Coherence Theory (Review of Quantum Mechanics, Quantization of the EM Field, Quantum Coherence Functions)

**Recommendations**

Solid mathematical background, good knowledge of classical electromagnetism and basic knowledge of quantum mechanics.

**Literature**

“Classical Electrodynamics” John David Jackson
“Theoretical Optics: An Introduction” Hartmann Römer
“Introduction to Fourier Optics” Joseph W. Goodman
“Introduction to the Theory of Coherence and Polarization of Light” Emil Wolf
“The Quantum Theory of Light” Rodney Loudon

**Workload**

total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies
Module: Nonlinear Optics [M-ETIT-100430]

Responsibility: Christian Koos
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory
Contained in: Advanced Optics & Photonics – Theory and Materials

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Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 Minutes
Modality of Exam: The oral exam is offered continuously upon individual appointment.

Conditions
There are no prerequisites for participating in the examination.
There is, however, a bonus system based on the problem sets that are solved during the tutorials: During the term, 3 problem sets will be collected in the tutorial and graded without prior announcement. If for each of these sets more than 70% of the problems have been solved correctly, a bonus of 0.3 grades will be granted on the final mark of the oral exam.

Qualification Objectives
The students
- understand and can mathematically describe the effect of basic nonlinear-optical phenomena using optical susceptibility tensors,
- understand and can mathematically describe wave propagation in nonlinear anisotropic materials,
- have an overview and can quantitatively describe common second-order nonlinear effects comprising the electro-optic effect, second-harmonic generation, sum- and difference frequency generation, parametric amplification and optical rectification,
- have an overview and can quantitatively describe the Kerr effect and other common third-order nonlinear effects, comprising self- and cross-phase modulation, four-wave mixing, self-focussing, and third-harmonic generation,
- have an overview and can describe nonlinear-optical interaction in active devices such as semiconductor optical amplifiers
- conceive the basic principles of various phase-matching techniques and can apply them to practical design problems,
- conceive the basic principles electro-optic modulators, can apply them to practical design problems, and have an overview on state-of-the art devices,
- conceive the basic principles third-order nonlinear signal processing and can apply them to practical design problems.

Content
1. The nonlinear optical susceptibility: Maxwell’s equations and constitutive relations, relation between electric field and polarization, formal definition and properties of the nonlinear optical susceptibility tensor,
2. Wave propagation in nonlinear anisotropic materials
3. Second-order nonlinear effects and devices: Linear electro-optic effect / Pockels effect, second-harmonic generation, sum- and difference-frequency generation, phase matching, parametric amplification, optical rectification
4. Third-order nonlinear effects and devices: Nonlinear refractive index and Kerr effect, self- and cross-phase modulation, four-wave mixing, self-focussing, third-harmonic generation
5. Nonlinear effects in active optical devices

**Recommendations**
Solid mathematical and physical background, basic knowledge in optics and photonics

**Literature**

**Workload**
Total 120 h, comprising 30 h lecture, 15 h problem class, 75 h homework and self-studies.
6 Advanced Optics & Photonics – Methods and Components

Module: Optoelectronic Components [M-ETIT-100509]

Responsibility: Wolfgang Freude
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory
Contained in: Advanced Optics & Photonics – Methods and Components

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-101907 Optoelectronic Components 4 Wolfgang Freude

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 Minutes
Modality of Exam: Oral examination, usually one examination day per month during the Summer and Winter terms. An extra questions-and-answers session will be held if students wish so.

Conditions
There are no prerequisites, but solution of the problems on the exercise sheet, which can be downloaded as homework each week, is highly recommended. Also, active participation in the problem classes and studying in learning groups are strongly advised.

Qualification Objectives
Comprehending the physical layer of optical communication systems. Developing a basic understanding which enables a designer to read a device’s data sheet, to make most of its properties, and to avoid hitting its limitations.
The students

- understand the components of the physical layer of optical communication systems
- acquire the knowledge of operation principles and impairments of optical waveguides
- know the basics of laser diodes, luminescence diodes and semiconductor optical amplifiers
- understand pin-photodiodes
- know the systems’ sensitivity limits, which are caused by optical and electrical noise

Content
The course concentrates on the most basic optical communication components. Emphasis is on physical understanding, exploiting results from electromagnetic field theory, (light waveguides), solid-state physics (laser diodes, LED, and photodiodes), and communication theory (receivers, noise). The following components are discussed:

- Light waveguides: Wave propagation, slab waveguides, strip wave-guides, integrated optical waveguides, fibre waveguides
- Light sources and amplifiers: Luminescence and laser radiation, luminescent diodes, laser diodes, stationary and dynamic behavior, semiconductor optical amplifiers
- Receivers: pin photodiodes, electronic amplifiers, noise

Recommendations
Minimal background required: Calculus, differential equations, Fourier transforms and p-n junction physics.
Literature
Detailed textbook-style lecture notes as well as the presentation slides can be downloaded from the IPQ lecture pages.
Further textbooks in German (also in electronic form) can be named on request.

Workload
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies
## Module: Fabrication and Characterisation of Optoelectronic Devices

**[M-ETIT-101919]**

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### ECTS & Recurrence

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### Learning Control / Examinations

- **Type of Examination:** written exam
- **Duration of Examination:** 120 Minutes
- **Modality of Exam:** One written exam offered at the end of each semester.

### Conditions

None.

### Qualification Objectives

The students build knowledge on process technology for the fabrication of a range of optoelectronic devices, including LEDs, solar cells, laser diodes, photodiodes, etc. They learn to compare the advantages of different technological approaches, including their economic boundary conditions. This is a technologically-based course where students will use their prior fundamental knowledge to gain a firm grasp on the fabrication sequences and characterisation (optical, electrical, electronic, materials) steps that are required to realise the above devices. While fulfilling the learning targets, the students

- possess the basic knowledge about the working principles of optoelectronic devices;
- comprehend the boundary conditions for the design of optoelectronic devices and have a good understanding of the challenges in microfabrication
- are familiar with different lithographic techniques, including e-beam lithography, optical lithography, multiple-photon lithography, X-ray lithography, etc.
- comprehend the different techniques that are available for thin-film deposition of dielectrics, metals and semiconductors
- understand what role micro-optics can play in such devices
- be able to determine the most promising characterisation techniques for evaluating material quality, electronic properties, as well as optical and electrical performance.
- Exposure to different dry- and wet-etching processes to help realise device structures
- have an understanding of the economic implications of the chosen technologies and their compatibility with high-throughput production

### Content

I. Overview: Opto-electronic Devices

II. Thin-film growth and deposition

- epitaxial growth of III-V semiconductors, as well as Si and Ge
- chemical vapour deposition (CVD) based processes, including atomic layer deposition (ALD)
• physical vapour deposition (PVD) based processes, including evaporation (thermal and e-beam) and sputtering (DC and RF)

III. Lithographic techniques
• e-beam lithography, optical lithography, laser interference lithography, two-photon lithography, X-ray lithography

IV. Etching processes
• wet- and dry-etching processes for semiconductors, dielectrics and metals

V. Micro-optics
• micro-optic design in opto-electronic devices

VI. Characterisation:
• materials properties (electron microscopy, crystallinity, bonding energies, elemeental concentrations, layer thicknesses ...)
• electronic properties (dopant profiling, mobility, minority carrier lifetimes, resistivity, bandgap measurements, ...)
• optical (spectrophotometry, photoluminescence, ...)
• electrical (current-voltage measurements, quantum efficiency / spectral response, ...)

VII. Excursion (TBA)

Recommendations
Semiconductor fundamentals

Literature
TBD

Workload
Total 90 h, hereof 30 h contact hours (24 h lecture, 6 h problem class), and 60 h homework and self-studies.
Module: Spectroscopic Methods (AO&P-MC-SM) [M-CHEMBIO-101900]

Responsibility: Manfred Kappes, Andreas-Neil Unterreiner
Organisation: KIT-Fakultät für Chemie und Biowissenschaften
Curricular Anchorage: Compulsory
Contained in: Advanced Optics & Photonics – Methods and Components

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Learning Control / Examinations
Type of Examination: written exam
Duration of Examination: 120 Minutes
Modality of Exam: The written exam is scheduled for the beginning of the break after the SS. A resit exam is offered at the end of the break. The exam consists of a set of problems that the students solve with the aid of certain allowed resources.

Conditions
One page of exercises is handed out to the students as homework each week. Solutions to these exercises can be presented by the students during exercises/tutorials on the blackboard on a voluntary basis. Participation in questions and answers during the lecture and tutorials is strongly supported and encouraged (though not a format requirement).

Qualification Objectives
The students get introduced into various methodologies of molecular spectroscopy in frequency and time domain. Due to different basic knowledge they first get acquainted with the microscopic physical background, but later on with the interpretation of the respective optical spectra and application in various fields. The students enhance their knowledge on spectroscopic equipment and optical components for the respective spectroscopic and/or microscopic technique.

- know the quantum mechanical basis of molecular rotational, vibrational and electronic spectroscopy
- conceive a microscopic understanding of optical excitation/deexcitation processes in molecules, i.e. light-matter interaction
- understand the interplay between spectroscopic method, experimental design and required optical components
- are familiar with sample preparation techniques in molecular spectroscopy (supersonic expansion, ion traps, soft-landing on surfaces, matrix-isolation)
- learn time scales of various molecular motions (especially rotation and vibration) before and during chemical/biochemical reactions
- will get in touch with timescales and frequencies of molecular properties and experience their interconnection

Content
I. Introduction to electronic spectroscopy (Born Oppenheimer approximation, Franck-Condon factor, relaxation processes)
II. Fluorescence spectroscopy and microscopy (Jablonski diagram, Kasha’s rule, Vavilov’s rule, kinetic and lifetime considerations, Stokes shift, Lippert equation, fluorescence anisotropy; confocal fluorescence microscopy, advanced microscopic methods, e.g. STED)
III. Well-defined sample techniques: spectroscopy in molecular beams, in ion traps and on surfaces (laser-induced fluorescence, cavity ringdown spectroscopy, matrix-isolation spectroscopy, photoelectron spectroscopy)
IV. Introduction to time-dependent phenomenon including time-dependent perturbation theory for selection rules, spectral
line shape

V. Generation and characterization of tunable laser pulses with pulse durations well below 1 picosecond

VI. Various methods of pump-probe spectroscopy covering the spectral range from the microwave to the X-ray regime

Recommendations
basic knowledge in physics (e.g. atomic/molecular quantum mechanics), light matter interaction

Literature
Demtröder: Laser Spectroscopy, Rullière: Femtosecond Laser Pulses, Atkins: Molecular Quantum Mechanics, various review articles

Workload
total 90 h, hereof 42 h contact hours (28 h lecture, 14 h problem class), and 48 h homework and self-studies
7 Adjustment Courses

7.1 Compulsory Modules

Module: Basic Molecular Cell Biology (AdjC-BMCB) [M-CHEMBIO-101903]

Responsibility: Martin Bastmeyer, Franco Weth
Organisation: KIT-Fakultät für Chemie und Biowissenschaften
Curricular Anchorage: Compulsory Elective
Contained in: Adjustment Courses / Compulsory Modules

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Compulsory

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Learning Control / Examinations
The written exam over 120 Minutes is scheduled for the beginning of the break after the SS.

Qualification Objectives
The students
- comprehend the fact that all life on earth is based on cells,
- understand the basic build-up of eukaryotic cells,
- know the central concepts of Organic and Physical Chemistry, on which life is based,
- know the structures and major functions of the four classes of biological macromolecules,
- comprehend the idea that a cell is a micro-factory based on nanomachines (proteins) that are instructed by informational macromolecules (DNA, RNA),
- conceive the idea that the variation of genomic information underlies evolution,
- know the methods of how cells acquire energy for life processes,
- are familiar with the roles of the cytoskeleton organelles and the cell membrane and
- are familiar with the basics of cellular responsitivity towards external cues,
- get a first glimpse on key technologies, which underlie experimental progress in the field

Content
I. Introduction to the cell
II. Concepts from Organic Chemistry pertinent to the Life Sciences
III. Concepts from Physical Chemistry pertinent to the Life Sciences
IV. Nucleic acids and proteins
V. Gene expression
VI. Methods
VII. Genomic variability and evolution
VIII. Cell membranes
IX. Energy metabolism
X. Cell signalling
XI. Cell compartments
XII. Cytoskeleton and cell division

Literature
Lecture presentations will be accessible in pdf-format.
Principles of Cell Biology, Plopper, G., Jones & Bartlett Publ., 2011

Prerequisites
7.2 Elective Modules

Module: Modern Physics [M-PHYS-101931]

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Compulsory

Learning Control / Examinations
Type of Examination: written exam
Duration of Examination: 180 Minutes
Modality of Exam: The written exam is scheduled in the beginning of each semester.

Conditions
None

Qualification Objectives
The students from different backgrounds refresh and elaborate their knowledge of basic physics. They comprehend the fundamentals of quantum physics and their application to atoms, nuclei and particles. They learn how to describe physical laws in a mathematical form and how to solve problems in modern physics by mathematical evaluation of these physical laws.

Learning targets
The students
- are familiar with the basic experimental results leading to Maxwell’s equations
- know how to apply Maxwell’s equations to simple problems in electromagnetism
- conceive the relation between relativity and electromagnetism
- comprehend the coherence of the particle and wave description of light and matter
- understand the basic principles leading to the Schrödinger-equation
- are able the apply the Schrödinger-equation to basic problems in quantum mechanics
- comprehend the limits of wave mechanics
- have a good understanding of atoms with many electrons
- know the fundamental properties of solids and especially the properties of electrons in crystalline solids.

Content
I. Introduction
II. Electromagnetism
III. Special Relativity
IV. Quantum mechanics
V. Atoms
VI. Solids

Recommendations
Solid mathematical background, basic knowledge in physics

Optics & Photonics (M.Sc.)
Module Handbook. Date 10/06/2017, Winter term 17/18
Literature
Paul A. Tipler: Physics for engineers and scientists
Paul A. Tipler: Modern Physics

Workload
total 180 h, hereof 75 h contact hours (60 h lecture, 15 h problem class), and 105 h homework and self-studies
Module: Measurement and Control Systems (AdjC-MCS) [M-MACH-101921]

Responsibility: Christoph Stiller
Organisation: KIT-Fakultät für Maschinenbau
Curricular Anchorage: Compulsory Elective
Contained in: Adjustment Courses / Elective Modules

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### Learning Control / Examinations

Type of Examination: written exam  
Duration of Examination: 150 Minutes  
Modality of Exam: The written exam is scheduled for the beginning of each break after the WS and after the SS.

### Conditions

None

### Qualification Objectives

The students
- possess knowledge in the theory of linear time-invariant systems in time domain, state space, and frequency domain
- can formulate a system model for practical devices
- can design a controller and assess closed-loop stability of the control loop
- understand the basic concept of measurement uncertainty and its propagation
- are able to estimate parameters from measurements
- understand the process and methodology of control engineering
- gather insight on interdisciplinary modelling for control of large and complex systems

### Content

I. Dynamic systems  
II. Properties of important systems and modeling  
III. Transfer characteristics and stability  
IV. State-space description  
V. Controller design  
VI. Fundamentals of measurement  
VII. Estimation  
VIII. Sensors  
IX. Introduction to digital measurement

### Recommendations

Solid mathematical background.

### Literature

C. Stiller: Measurement and Control, scriptum  
R. Dorf and R. Bishop: Modern Control Systems, Addison-Wesley

**Workload**

total 180 h, hereof 60 h contact hours (45 h lecture, 15 h problem class), and 120 h homework and self-studies, an additional tutorial is offered
8 Optics & Photonics Lab

**Module: Optics and Photonics Lab [M-PHYS-102189]**

**Responsibility:** Michael Hetterich

**Organisation:** KIT-Fakultät für Physik

**Curricular Anchorage:** Compulsory

**Contained in:** Optics & Photonics Lab

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**Identifier** | **Course** | **ECTS Responsibility**
--- | --- | ---
T-PHYS-104511 | Optics and Photonics Lab | 10 | Michael Hetterich

**Learning Control / Examinations**
At the beginning of the first semester, the students choose a number of labs from the list of lab descriptions provided on a first come, first served basis (e-mail to the lab coordinator, currently tobia.siegle@kit.edu, so that they can be registered with the respective department’s labs. The successful completion of an individual lab is awarded by a certain number of lab units (specified in the list, one lab unit roughly corresponds to 1/2 day’s work). In order to pass, the students have to collect at least 15 lab units from the Department of Electrical Engineering and Information Technology must be chosen.

**Conditions**
Before each lab the corresponding supervisor must be contacted in order to obtain the required preparation material. In a short interview before the actual lab, the supervisor checks if the students are properly prepared. For each lab a written report / data analysis has to be handed in to the supervisor. Based on the interview, the lab work and the report, the individual labs are marked with “+”, “0” or “-”. If marked “-” overall or in one of its parts, the individual lab has to be repeated (or substituted by another one), otherwise the corresponding number of lab units will be awarded. Upon completion of the whole module (I+II, a minimum of 15 lab units in total), the students are awarded 10 credit points.

**Qualification Objectives**
The students apply their theoretical knowledge in optics and photonics from the fundamental modules in practical lab work. They learn how to prepare and carry out experiments, analyse the obtained data as well as how to summarize and discuss their results in a scientific report.

The students
- can design, build, align, and utilize optical set-ups
- are familiar with optical devices (e.g., lasers, organic light-emitting diodes, detectors, solar cells, optical fibers) and systems (e.g., machine vision, optical tweezers)
- understand interferometric methods
- know optics-related fabrication techniques
- understand various types of optical spectroscopy
- are familiar with practical applications of optical systems in physics, engineering, chemistry, and biology
- are able to scientifically analyse experimental data and critically discuss their results
- can write a scientific report

**Content**
The Optics & Photonics Lab comprises a series of different labs covering a wide range of topics from advanced laboratories of the Departments of Physics, Electrical Engineering and Information Technology, Mechanical Engineering, as well as Chemistry and Bio-Sciences.

The students will deepen and apply their theoretical knowledge from the fundamental modules by exploring different aspects of optics and photonics from optical spectroscopy (absorption and transmission spectroscopy of semiconductors, Zeeman...
effect, magneto-optical Kerr effect, femtosecond spectroscopy, Raman spectroscopy, ...), interferometers (Fabry-Pérot, Mach–Zehnder), and fundamental quantum optics (quantum eraser) up to devices (e.g., solar cells, organic light-emitting diodes, fluorescent lamps, optical sensors), fiber optics, nanotechnology, integrated optics, and finally optical systems and their applications (e.g., cognitive automobile labs / machine vision, biological fluorescence microscopy, optical tweezers, etc.).

The number of labs in the different areas is constantly growing and evolving. Therefore, at the beginning of the first semester, a list with descriptions of the individual labs currently offered by the different faculties is provided to the students.

Recommendations
Basic background in optics and photonics, as well as physics.

Literature
Preparation material for the labs including descriptions of the set-ups, tasks to perform, and the required background information / literature etc. are provided by the supervisors of the individual experiments beforehand.

Workload
Total 300 h (split between WS and SS) hereof 60 h contact hours (lab work) and 240 h preparation, data analysis, and report writing.
Module: Seminar Course  [M-PHYS-102195]

Responsibility: David Hunger

Organisation: KIT-Fakultät für Physik

Curricular Anchorage: Compulsory

Contained in: Seminar Course (Research Topics in Optics & Photonics)

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Compulsory

Identifier Course ECTS Responsibility
T-PHYS-104516 Seminar Course 4 David Hunger

Learning Control / Examinations
Type of Examination: seminar talk
Modality of Examination: Every student has to present a scientific talk of about 30 minutes duration followed by a scientific discussion and a feedback on the presentation style. No mark is given.

Conditions
To acquire the credit points (4CP) a talk has to be given and the student has to attend all talks of the peers in her/his group.

Qualification Objectives
This common seminar gives an overview over the research in optics and photonics at KSOP. It provides for the students a balance between their specialization and an indispensable broad background. Furthermore, the students will learn how to present a scientific topic to a peer audience.

The students
- acquire skills in presentation techniques like Power Point
- learn how to present a scientific topic to a peer audience
- learn how to defend a topic in a scientific discussion
- can improve their presentation skills due to feedback from the audience
- get in-depth insight into a special research topic
- get a broad background on topical research in optics & photonics

Content
The Seminar Course comprises a series of talks covering a wide range of topics from the research of the KSOP PI groups. The students are split into two groups of about 20 students each. Every student gives a presentation on a topic chosen from a list provided on the KSOP sharepoint. Typical topics are “Photonic Waveguides”, “Image Stitching”, “Optical Frequency Multiplexing”, “Surface Polaritons”, “Random Lasing”, “Digital Holography”, “Imaging of Living Cells”, “Organic Solar Cells”, “Quantum Computer”, “Optical Tweezers”, “Biophotonic Sensors”, “Optical Nanoantennas”, and more. The preparation of the talks is assisted by researchers from the KSOP PI groups.

The seminar topics are constantly adapted to the current research within KSOP.

Recommendations
Basic background in optics and photonics.

Literature
Literature is provided by the supervisors of the individual talks beforehand.

Workload
total 120 h, hereof 30 h contact hours (seminar) and 90 h preparation of talk and self-studies
10 Additive Key Competences

Module: German at ID A1.1 (AKC-GLC) [M-IDSCHOOLS-102198]

Responsibility: Miriam Sonnenbichler
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Additive Key Competences

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Compulsory

Identifier Course ECTS Responsibility
T-IDSCHOOLS-104528 German at ID A1.1 - Exam 4 Tina Krebs
T-IDSCHOOLS-105190 German Language Course A1.1 - Attendance 0 Tina Krebs

Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 90 Minutes
Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

Conditions
Regular attendance (80%), active participation in class; presentation; successful completion of written homework and tests during the lecture period

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course conveys first competencies on level A1 of GER:
Can understand and use familiar everyday expressions and very basic phrases aimed at the satisfaction of needs of a concrete type. Can introduce him/herself and others and can ask and answer questions about personal details such as where he/she lives, people he/she knows and things he/she has. Can interact in a simple way provided the other person talks slowly and clearly and is prepared to help.

Content
Cultural Studies:
1. Introducing oneselfs and others, greetings and farewells, when to use du and Sie
2. Germany across Europe
3. Punctuality, leisure activities, German cuisine
4. Public transport, festivals in the German speaking countries

Spoken and written interaction:
greeting someone, initiating a conversation, introducing oneself and others, asking for somebody’s name and where she/he is from, spelling, ordering and paying drinks, understanding and giving phone numbers, naming and asking for things in the classroom, talking about countries and cities, their geographical locations and sights, the languages spoken there, describing a diagram, writing little texts about oneself, describing a flat, understanding and telling time, describing one’s daily routine, making appointments and dates, apologizing for being late, telling where people work and live, telling how people get to work, in a big building: asking for people and directions, setting up appointments on the phone

Grammar:
Verbs in german, present tense, present tense verb conjugation, irregular and regular verbs, nouns, prepositions bei, als, in, aus, grammatical person in plural, negation nicht, numbers, word order in statements, ja-nein-doch, verbs with a vowel change, possessive pronouns, definite article der, die, das, personal pronouns er, es, sie, prices, particle denn, indefinite article ein, eine, negative article kein/e, singular and plural, accusative, modal auxiliaries and sentences brackets, modal auxiliary können, irregular verbs with vowel changes, expressing astonishment and approval, telling the time, word formation

Learning techniques:
identify international words, classify words, use flashcards and “phrase boxes”, use dictionaries, complete or formulate own grammar rules, develop grammar tables, note taking strategies, use wordnets

Recommendations
No previous knowledge of the German language required, but strong motivation and readiness for autonomous language learning, as a language portfolio has to be kept.

Literature
Coursebook:

Workbook:

Workload
total 120h, here of 45h contact hours, 75h homework and self-study and preparation for exam
Module: German at ID A2.1  [M-IDSCHOOLS-102357]

Responsibility: Miriam Sonnenbichler

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Additive Key Competences

Additional Achievements

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Learning Control / Examinations

Type of Examination: 70% written exam, 30% spoken performance

Duration of Examination: 90 Minutes

Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

Conditions

Regular attendance (80%), active participation in class; presentation; successful completion of written homework and tests during the lecture period

Qualification Objectives

This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course conveys first competencies on level A2 of GER:

The students can understand sentences and frequently used expressions related to areas of most immediate relevance (e.g. very basic personal and family information, shopping, local geography, employment). Can communicate in simple and routine tasks requiring a simple and direct exchange of information on familiar and routine matters. Can describe in simple terms aspects of his/her background, immediate environment and matters in areas of immediate need.

Content

Cultural Studies:

1. handle relocation
2. manage to buy food
3. handling of topics like health, sport and spa in German culture
4. being in restaurant

Spoken and written interaction:

family, activities, events, institutions, relocations, nature, landscapes, foodstuff, packages, weights, tourism, events, sports, illnesses, accidents, being in restaurants, commodities
ADDITIVE KEY COMPETENCES

Grammer:
subjunctive I, reflexive verbs, perfect, past tense of: sein, haben, word creation: suffix -er + -ung, adjective declination, after articles, possessive article in different cases, changing prepositions, verbs with changing prepositions, temporal prepositions, temporal adverbs, conjunctions: weil, deshalb, dass, wenn

Recommendations
Successful completion of A1.2 and a strong motivation and readiness for autonomous language learning

Literature
Coursebook:

Workbook:

Dictionary:
Bilingual dictionary

Workload
total 120h, hereof 45h contact hours, 75h homework and self-study and preparation for exam
Module: German at ID B1.1 [M-IDSCHOOLS-102359]

Responsibility: Miriam Sonnenbichler

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Additive Key Competences

Additional Achievements

ECTS 4

Recurrence Each winter term

Duration 1 term

Language German

Version 2

Compulsory

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Learning Control / Examinations

Type of Examination: 70% written exam, 30% spoken performance

Duration of Examination: 90 Minutes

Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

Conditions

Regular attendance ( 80%), active participation in class; presentation; successful completion of written homework and tests during the lecture period

Qualification Objectives

This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course conveys first competencies on level B1 of GER:

The students can understand the main points of clear standard input on familiar matters regularly encountered in work, school, leisure, etc. Can deal with most situations likely to arise whilst travelling in an area where the language is spoken. Can produce simple connected text on topics which are familiar or of personal interest. Can describe experiences and events, dreams, hopes and ambitions and briefly give reasons and explanations for opinions and plans.

Content

Cultural Studies:

1. building the language conditions to make friends
2. German service behavior
3. career choice and possibilities in Germany
4. understanding of joy and luck in different cultures

Spoken and written interaction:

traits, work, living, customer service, media, technique, invitations for dinner, animals, advices, strengths, weaknesses, health, doing sport, nutrition, breakdowns in everyday life, moments of happiness, events in companies
ADDITIVE KEY COMPETENCES

Grammar:
infinitive with zu, subjunctive II, comparative, superlative, declination in genitive, preposition: trotz, past tense, future I,
pluperfect with: sein + haben, word creation: adjectives as nouns, n-declination, relative clauses, relative clauses with
prepositions, conjunctions: obwohl, trotzdem, falls, da während, bevor, nachdem

Recommendations
Successful completion of A2.2 and a strong motivation and readiness for autonomous language learning

Literature
Coursebook:

Workbook:
978-3-19-111903-4

Dictionary:
Bilingual dictionary

Workload
total 120h, hereof 45h, contact hours, 75h homework and self-study and preparation for exam
Module: Business Innovation in Optics and Photonics  [M-ETIT-101834]

Responsibility: Werner Nahm
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Additive Key Competences
Additional Achievements

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Learning Control / Examinations
Type of Examination: Case study Presentation
Duration of Examination: 60 Minutes
Modality of Exam: The exam is a presentation of the case work by the team in front of the KIT lecturer and the R&D and innovation managers of the Carl Zeiss AG. Also a presentation on the group work on technical aspects earlier in the course is taken into account for the examination.

Qualification Objectives
The student has an understanding how innovative concepts for optical and photonics products are transferred into a successful business development. The student knows about and makes first hands on experiences on business development aspects in a technology start up environment. The students acquire specialized knowledge in technologies and applications in the field of smart mobile solutions for optical applications as well as an introduction into the field of patent rights. The students can organize themselves in groups and distribute and execute tasks. Further they gain competences in the fields teamwork, organization and communication.

- understand the implications of intellectual property
- are able to perform data base research
- know how to develop a business plan
- get an understanding of how to design a project
- are able to develop in small groups innovative business cases for a potential future product

Content
This course is instructed and presented by external innovation specialists of the R&D, business and management departments of the Carl Zeiss AG.

- Introduction: Examples of existing smart mobile device applications, Brainstorming for ideas
- Technology Introduction: Mobile device technology, Optic components, Display technology (LCD, OLED), Tracking and Sensor Technologies in smart mobile devices
- Group Work Technology
- Group Presentations Technology
- Business Case Development/ Business Plan: Market segmentation, Market research, Essentials of finance, How to write a business plan?
- Project Design: How to run an agile R&D Project?, Traget costing, Networked product development
- Agile project simulation
ADDITIVE KEY COMPETENCES

- Group Work
- Excursion to Carl Zeiss AG in Oberkochen (full day)
- Presentation of results of the group work to the new business experts committee of the Carl Zeiss AG

Recommendations
Personal motivation and interest for getting deeper into business development aspects, methods and tools. Commitment to active, regular and continuous participation in the group work.

Workload
total 120 h, thereof 34 h contact hours and 86 h preparation, homework, self-studies and excursion
Module: German at ID A1.2 (AKC-GLC) [M-IDSCHOOLS-102281]

Responsibility: Tina Krebs
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Additive Key Competences, Additional Achievements

ECTS | Recurrence | Duration | Language | Version
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4 | Each summer term | 1 term | German | 2

Compulsory

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Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 90 Minutes
Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

Conditions
Regular attendance (80%), active participation in class, successful completion of written homework and tests during the lecture period.

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)
This course is suited for all students, PhD students, post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.
The language course completes competencies on level A1 of GER:
The students can understand and use familiar everyday expressions and very basic phrases aimed at the satisfaction of needs of a concrete type. Can introduce him/herself and others and can ask and answer questions about personal details such as where he/she lives, people he/she knows and things he/she has. Can interact in a simple way provided the other person talks slowly and clearly and is prepared to help.

Content
Cultural Studies:
1. ask for and give route descriptions, living in German cities
2. make appointments, speak about arches and pains
3. character traits, rules in household and society
4. evaluate: clothes, weather, celebrations

Spoken and written interaction:
Institutions and places in town, apartments and houses, being hotel, plans and wishes, human body, appearance, character, everyday household tasks, traffic rules, environment, clothing, weather, cardinal points, celebrations
ADDITIVE KEY COMPETENCES

Grammar:
Genitive of proper names, possessive articles: sein/ihr, personal pronouns in Dative and Accusative, verbs with Dative, imperative, modal verbs: wollen/sollen/dürfen/müssen, syntax of modal verbs past tense: sein/haben, perfect, subjunctive, prepositions: mit/ohne, local prepositions, temporal prepositions, conjunction: den, comparison of adjectives, word formation: adjective with un-/los, ordinal numbers, wann question

Recommendations
Successful completion of A1.1 and a strong motivation and readiness for autonomous language learning

Literature
Coursebook:

Workbook:

Dictionary:
Bilingual dictionary

Workload
total 120 h, hereof 45 h contact hours, 75 h homework and self-studies and preparation for exam
Module: German at ID A2.2 (AKC-GLC) [M-IDSCHOOLS-103208]

Responsibility: Tina Krebs
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Additive Key Competences, Additional Achievements

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Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 90 Minutes
Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

Conditions
Regular attendance (80%), active participation in class, presentation, successful completion of written homework and tests during the lecture period

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Master or proficiency)

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course completes competencies on level A2 of GER:
The students can understand sentences and frequently used expressions related to areas of most immediate relevance (e.g. very basic personal and family information, shopping, local geography, employment). Can communicate in simple and routine tasks requiring a simple and direct exchange of information on familiar and routine matters. Can describe in simple terms aspects of his/her background, immediate environment and matters in areas of immediate need.

Content
Cultural Studies:
1. German press + media
2. culture Events in different countries
3. cities and City Administration in Germany
4. mobility + traffic in Germany

Spoken and written interaction:
study tips, post, media, being in hotel, travels, traffic, weather, events, press, books, documents, internet/online registrations, schools, education + training, mobility, foreign countries
ADDITIVE KEY COMPETENCES

Grammar:
question articles, demonstrative pronouns, passive in present tense, verbs in different cases, verbs with prepositions in
different cases, modal verbs in past tense, past tense, local prepositions: gegenüber von, an... vorbei, durch, conjunctions:
bis, seit, positions of objects, indirect questions, question- and prepositional adverbs

Recommendations
Successful completion of A2.1 and a strong motivation and readiness for autonomous language learning

Literature
Coursebook:
978-3-19-301902-8

Workbook:
978-3-19-311902-5

Dictionary:
Bilingual dictionary

Workload
total 120h, here of 45h contact hours, 75h homework and self-study and preparation for exam
Module: German at ID B1.2  [M-IDSCHOOLS-103230]

**Responsibility:**  Tina Krebs

**Organisation:**  KIT-Fakultät für Elektrotechnik und Informationstechnik

**Curricular Anchorage:**  Compulsory Elective

**contained in:**  Additive Key Competences

**Additional Achievements**

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**Learning Control / Examinations**

Type of Examination: 70% written exam, 30% spoken performance

Duration of Examination: 90 Minutes

Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

**Conditions**

Regular attendance (80%), active participation in class; presentation; successful completion of written homework and tests during the lecture period.

**Qualification Objectives**

This course is designed to assist students in developing basic German language skills, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency).

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course completes competencies on level B1 of GER:

The students can understand the main points of clear standard input on familiar matters regularly encountered in work, school, leisure, etc. Can deal with most situations likely to arise whilst travelling in an area where the language is spoken. Can produce simple connected text on topics which are familiar or of personal interest. Can describe experiences and events, dreams, hopes and ambitions and briefly give reasons and explanations for opinions and plans.

**Content**

Cultural Studies:

1. how to apply in Germany
2. politics and German politicians
3. brief introduction to German History
4. German environmental behavior

Spoken and written interaction:

synonyms, continuing education, applications, memories of relations, art, painting, politics, society, landscape, tourism, guestbook entry, concerts, events, history, environment, climate, future visions
ADDITIVE KEY COMPETENCES

Grammar:
established terms with es, nicht/nur brauchen + infinitive with zu, passive in present, past tense and perfect, passive and modal verbs, causal prepositions with genitive, local prepositions, temporal prepositions, conjunctions: causes and consequences, two-part conjunctions, funds and results, main and subordinate clause, subjunctive II, darum, deshalb, deswegen, aus diesem Grund, daher, sowohl...als auch, nicht nur...sondern auch, entweder...oder, weder...noch, zwar...aber, je...desto/umso..., indem..., sodass, (an)statt/ohne dass, damit/um...zu

Recommendations
Successful completion of B1.1 and a strong motivation and readiness for autonomous language learning.

Literature
Coursebook:

Workbook:

Dictionary:
Bilingual dictionary

Workload
total 120 h, hereof 45 h contact hours, 75 h homework and self-studies and preparation for exam.
Module: German at ID B2.1 (AKC-GLC) [M-IDSCHOOLS-103533]

Responsibility: Tina Krebs
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Additive Key Competences, Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-IDSCHOOLS-107057 German at ID B2.1 - Exam 4 Tina Krebs

Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 120 Minutes
Modality of Exam: 70% written exam in the end of the lecture period, 30% vrebal exam: active participation during the lessons and a presentation

Conditions
Regular attendance (80%), active participation in class; presentation; successful completion of written homework and tests during the lecture period.

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course conveys competencies on level B2 of GER.

By the end of this course, students will be able to understand the main ideas of complex text on both concrete and abstract topics, including technical discussions in his/her field of specialisation. Can interact with a degree of fluency and spontaneity that makes regular interaction with native speakers quite possible without strain for either party. Can produce clear, detailed text on a wide range of subjects and explain a viewpoint on a topical issue giving the advantages and Independent disadvantages of various options.

Content
Cultural Studies:

1. Comparing diefferent cultural phenomena and regarding their influence on language
2. German working live
3. modern families and Relationship models
4. Universities in Germany

Spoken and written interaction:
Correct use of German idioms
Terminology in different incidents, specialized language
Focus on the role of grammar structures to underline a statement
Language tools to set differentiated thesis

Grammar:
fixed unit of nouns with prepositions and nouns with verbs, subjective significance of: sollen, nominalizations of verbs, various connectors, word creation, negation through word creation, alternatives for passive, forms of passive, participle I+II as adjective, reference words, wenn+dass sentences, temporal expressions

Learning techniques:
work with authentic texts, videos and listening texts, discussions - set up own theses, create written statements

Recommendations:
the German level B1.2 should be fulfilled and there should be a strong motivation and readiness for autonomous language learning, as a language portfolio has to be kept.

Recommendations
Successful completion of B1.2 and a strong motivation and readiness for autonomous language learning

Literature

Coursebook:

Dictionary:
Bilingual dictionary

Workload
total 120 h, hereof 45 h contact hours, 75 h homework and self-studies and preparation for exam
Module: German at ID B2.2 (AKC-GLC) [M-IDSCHOOLS-103536]

Responsibility: Tina Krebs
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Additive Key Competences, Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-IDSCHOOLS-107060 German at ID B2.2 - Exam 4 Tina Krebs

Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 120 Minutes
Modality of Exam: 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation

Conditions
Regular attendance (80%), active participation in class; presentation, successful completion of written homework and test during the lecture period

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and rading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)
This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.
The language course conveys competencies on level B2 of GER.
By the end of this course, students will be able to understand the main ideas of complex text on both concrete and abstract topics, including technical discussions in his/her field of specialisation. Can interact with a degree of fluency and spontaneity that makes regular interaction with native speakers quite possible without strain for either party. Can produce clear, detailed text on a wide range of subjects and explain a viewpoint on a topical issue giving the advantages and Independent disadvantages of various options.

Content
Cultural Studies:
1. Comparing different cultural phenomena and regarding their influence on language
2. German working live
3. modern families and Relationship models
4. Universities in Germany

Spoken and written interaction:
Correct use of German idioms
Terminology in different incidents, specialized language
Focus on the role of grammar structures to underline a statement
Language tools to set differentiated thesis

Grammar:
fixed unit of nouns with prepositions and nouns with verbs, subjective significance of: *sollen*, nominalizations of verbs, various connectors, word creation, negation through word creation, alternatives for passive, forms of passive, participle I+II as adjective, reference words, *wenn+dass* sentences, temporal expressions

Learning techniques:
work with authentic texts, videos and listening texts, discussions - set up own theses, create written statements

Recommendations:
the German level B2.1 should be fulfilled and there should be a strong motivation and readiness for autonomous language learning, as a language portfolio has to be kept.

Recommendations
Successful completion of B2.1 and a strong motivation and readiness for autonomous language learning

Literature
Coursebook:

Dictionary:
Bilingual dictionary

Workload
total 120 h, hereof 45 h contact hours, 75 h homework and self-studies and preparation for exam
Module: Laser Physics [M-ETIT-100435]

Responsibility: Christian Koos
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Biomedical Photonics / Elective Modules
Specialization / Specialization - Optical Systems
Additional Achievements

Compulsory

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Learning Control / Examinations

Type of Examination: Oral examination
Duration of Examination: 30 minutes
Modality of Exam: The oral exam is scheduled for the beginning of the break after the WS.

Conditions

No formal prerequisites. However, steady participation in lecture and tutorial as well as thorough preparation based on the scriptum is highly recommended.

Qualification Objectives

The students

- know the fundamental relations and background of lasers
- gain the necessary knowledge for understanding and dimensioning of lasers, laser media, optical resonators and pump strategies
- understand the pulse generation with lasers and their fundamental relations
- obtain the necessary knowledge on several lasers; gas-, solid state, fiber- and disc-lasers in the visible and middle infrared range

Content

1 Quantum-mechanical fundamentals of lasers
1.1 Einstein relations and Planck’s law
1.2 Transition probabilities and matrix elements
1.3 Mode structure of space and the origin of spontaneous emission
1.4 Cross sections and broadening of spectral lines
2 The laser principles
2.1 Population in version and feedback
2.2 Spectroscopic laser rate equations
2.3 Potential model of the laser
3 Optical Resonators
3.1 Linear resonators and stability criterion
3.2 Mode structure and intensity distribution
3.3 Line width of the laser emission
4 Generation of short and ultra-short pulses
4.1 Basics of Q-switching
4.2 Basics of mode locking and ultra-short pulses
5 Laser examples and their applications
5.1 Gas lasers: The Helium-Neon-Laser
5.2 Solid-state lasers
5.2.1 The Nd³⁺-Laser
5.2.2 The Tm³⁺-Laser
5.2.3 The Ti³⁺:Al₂O₃ Laser
5.3 Special realisations of lasers
5.3.1 Thermal lensing and thermal stress
5.3.2 The fiber laser
5.3.3 The thin-dis laser

Recommendations
Solid mathematical background, basic knowledge in physics

Literature
M. Eichhorn, Laser physics (Springer)
M. Eichhorn, Laserphysik (Springer)
A. E. Siegman, Lasers (University Science Books)
B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics (Wiley-Interscience)
F. K. Kneubühl, M. W. Sigrist, Laser (Teubner)

Workload
total 120 h, hereof 45 h contact hours (30 h lectures, 15 h tutorial) and 75 h recapitulation and self-studies
Module: Optical Transmitters and Receivers  [M-ETIT-100436]

Responsibility: Wolfgang Freude

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100639 Optical Transmitters and Receivers 4 Wolfgang Freude

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 Minutes
Modality of Exam: Oral examination, usually one examination day per month during the Summer and Winter terms. An extra questions-and-answers session will be held if students wish so.

Conditions
Exercise sheet can be downloaded as homework each week. Active participation in the problem classes is advised. Studying in learning groups is strongly recommended.

Qualification Objectives
The students understand the peculiarities of optical communications, and how optical signals are generated, transmitted and received,
know about sampling, quantization and coding,
learn the basics about noise on reception,
understand the properties of a linear and a nonlinear optical fibre channel,
grasp the idea of channel capacity and spectral efficiency,
know about various forms of modulation,
acquire knowledge of optical transmitter elements,
understand the function of optical amplifiers,
have a basic understanding of optical receivers,
know the sensitivity limits of optical systems, and
understand how these limits are measured.

Content
The course concentrates on basic optical communication concepts and connects them with the properties of physical components. The following topics are discussed:

- Advantages and limitations of optical communication systems
- Optical transmitters comprising lasers and modulators
- Optical receivers comprising direct and heterodyne reception
- Characterization of signal quality

Recommendations
Minimal background required: Calculus, differential equations, Fourier transforms and p-n junction physics
11  SPECIALIZATION

11.1  Specialization - Photonic Materials and Devices

**Literature**

Detailed textbook-style lecture notes can be downloaded from the IPQ lecture pages.


In German. Since 1997 out of print.

Electronic version available via w.freude@kit.edu.

Kaminow, I. P.; Li, Tingye; Willner, A. E. (Eds.): Optical Fiber Telecommunications VI A: Components and Subsystems +VI B:


**Workload**

Total 120 h, hereof 33 h contact hours, (15 x 1.5 h = 22h lecture, 15 x 0.75 h = 11 h problem class), and 97 h homework and self-studies
Module: Optical Waveguides and Fibers [M-ETIT-100506]

Responsibility: Christian Koos
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Additional Achievements

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Compulsory

Identifier | Course | ECTS | Responsibility
---|---|---|---
T-ETIT-101945 | Optical Waveguides and Fibers | 4 | Christian Koos

Learning Control / Examinations
Type of Examination: Oral
Duration of Examination: 20 Minutes
Modality of Exam: The written exam is offered continuously upon individual appointment.

Conditions
There are no prerequisites for participating in the examination.
There is, however, a bonus system based on the problem sets that are solved during the tutorials: During the term, 3 problem sets will be collected in the tutorial and graded without prior announcement. If for each of these sets more than 70% of the problems have been solved correctly, a bonus of 0.3 grades will be granted on the final mark of the oral exam.

Qualification Objectives
The students
- conceive the basic principles of light-matter-interaction and wave propagation in dielectric media and can explain the origin and the implications of the Lorentz model and of Kramers-Kronig relation,
- are able to quantitatively analyze the dispersive properties of optical media using Sellmeier relations and scientific databases,
- can explain and mathematically describe the working principle of an optical slab waveguide and the formation of guided modes,
- are able to program a mode solver for a slab waveguide in Matlab,
- are familiar with the basic principle of surface plasmon polariton propagation,
- know basic structures of planar integrated waveguides and are able to model special cases with semi-analytical approximations such as the Marcatili method or the effective-index method,
- are familiar with the basic concepts of numerical mode solvers and the associated limitations,
- are familiar with state-of-the-art waveguide technologies in integrated optics and the associated fabrication methods,
- know basic concepts of of step-index fibers, graded-index fibers and microstructured fibers,
- are able to derive and solve basic relations for step-index fibers from Maxwell’s equations,
- are familiar with the concept of hybrid and linearly polarized fiber modes,
- can mathematically describe signal propagation in single-mode fibers design dispersion-compensated transmission links,
- conceive the physical origin of fiber attenuation effects,
- are familiar with state-of-the-art fiber technologies and the associated fabrication methods,
- can derive models for dielectric waveguide structures using the mode expansion method,
- conceive the principles of directional couplers, multi-mode interference couplers, and waveguide gratings,
- can mathematically describe active waveguides and waveguide bends.
Content

1. Introduction: Optical communications
2. Fundamentals of wave propagation in optics: Maxwell’s equations in optical media, wave equation and plane waves, material dispersion, Kramers-Kroig relation and Sellmeier equations, Lorentz and Drude model of refractive index, signal propagation in dispersive media.
3. Slab waveguides: Reflection from a plane dielectric boundary, slab waveguide eigenmodes, radiation modes, inter- and intramodal dispersion, metal-dielectric structures and surface plasmon polariton propagation.
4. Planar integrated waveguides: Basic structures of integrated optical waveguides, guided modes of rectangular waveguides (Marcatili method and effective-index method), basics of numerical methods for mode calculations (finite difference- and finite-element methods), waveguide technologies in integrated optics and associated fabrication methods
5. Optical fibers: Optical fiber basics, step-index fibers (hybrid modes and LP-modes), graded-index fibers (infinitely extended parabolic profile), microstructured fibers and photonic-crystal fibers, fiber technologies and fabrication methods, signal propagation in single-mode fibers, fiber attenuation, dispersion and dispersion compensation
6. Waveguide-based devices: Modeling of dielectric waveguide structures using mode expansion and orthogonality relations, multimode interference couplers and directional couplers, waveguide gratings, material gain and absorption in optical waveguides, bent waveguides

Recommendations
Solid mathematical and physical background, basic knowledge of electrodynamics

Literature
B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics
G.P. Agrawal: Fiber-optic communication systems
C.-L. Chen: Foundations for guided-wave optics
Katsunari Okamoto: Fundamentals of Optical Waveguides
K. Iizuka: Elements of Photonics

Workload
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial) and 75 h homework and self-studies.
Module: Solar Energy [M-ETIT-100524]

**Responsibility:** Bryce Sydney Richards

**Organisation:** KIT-Fakultät für Elektrotechnik und Informationstechnik

**Curricular Anchor:** Compulsory Elective

**Contained in:**
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Solar Energy / Compulsory Modules
- Additional Achievements

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### Learning Control / Examinations

- **Type of Examination:** written exam
- **Duration of Examination:** 120 Minutes
- **Modality of Exam:** One written exam at the end of each semester.

### Conditions

Active participation in the lectures and problem classes.

### Qualification Objectives

The students:

- understand the basic working principle of pn-junction solar cells,
- learn about the different kinds of solar cells (crystalline and amorphous silicon, CIGS, Cadmium telluride, organic, dye-sensitized solar cells, etc.),
- get an overview over upcoming third-generation photovoltaic concepts,
- receive information on photovoltaic modules and module fabrication,
- develop an understanding of solar cell integration and feeding the electrical power to the grid,
- get insight into solar concentration and tandem solar cells for highly efficient energy conversion,
- compare photovoltaic energy harvesting with solar thermal technologies
- understand the environmental impact of solar energy technologies.

Die Studentinnen und Studenten können in englischer Fachsprache sehr gut kommunizieren.

### Content

I. Introduction: The Sun
II. Semiconductor fundamentals
III. Solar cell working principle
IV. First Generation solar cells: silicon wafer based
V. Second Generation solar cells: thin films of amorphous silicon, copper indium gallium diselenide, cadmium telluride, organic photovoltaics and dye sensitized solar cells
V. Third Generation Photovoltaics: high-efficiency device concepts incl. tandem solar cells
VI. Modules and system integration
VII. Cell and module characterization techniques
VIII. Economics, energy pay-back time, environmental impact
IX. Other solar energy harvesting processes, incl. thermal and solar fuels
X. Excursion

### Recommendations

Semiconductor fundamentals
11.1 Specialization - Photonic Materials and Devices

**Literature**

P. Würfel: Physics of Solar Cells  
V. Quaschning: Renewable Energy Systems  

**Workload**

Total 180 h, herof 60 h contact hours (45 h lecture, 15 h problem class), and 120 h homework and self-studies
Module: Field Propagation and Coherence  [M-ETIT-100566]

Responsibility:  Wolfgang Freude

Organisation:  KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage:  Compulsory Elective

Contained in:  Specialization / Specialization - Photonic Materials and Devices
               Specialization / Specialization - Optical Systems
               Additional Achievements

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Learning Control / Examinations

Type of Examination: oral exam
Duration of Examination: 30 Minutes

Modality of Exam: Oral examination, usually one examination day per month during the summer and winter terms. An extra questions-and-answers session will be held for preparation if students wish so.

Conditions

There are no prerequisites, but solution of the problems on the exercise sheet, which can be downloaded as homework each week, is highly recommended. Also, active participation in the problem classes and studying in learning groups are strongly advised.

Qualification Objectives

Presenting in a unified approach the common background of various problems and questions arising in general optics and optical communications

The students

- know the common properties of counting of modes, density of states and the sampling theorem
- comprehend the relationship between propagation in multimode waveguides, mode coupling, MMI and speckles
- can analyze propagation in homogeneous media with respect to system theory, antennas, and the resolution limit of optical instruments
- understand that coherence as a general concept comprises coherence in time, in space and in polarization
- comprehend the implication of complete spatial incoherence, and what is the radiation efficiency of a source with a diameter smaller than a wavelength (the mathematical Hertzian dipole, for instance)
- can assess when can two incandescent bulbs form an interference pattern in time
- know under which conditions a heterodyne radio receiver, which is based on a non-stationary interference, actually works

Content

The following selection of topics will be presented:

- Light waves, modes and rays: Longitudinal and transverse modes, sampling theorem, counting and density of modes ("states")
- Propagation in homogeneous media: Resolution limit. Non-paracial and paracial optics. Gaussian beam. ABCD matrix

**Recommendations**
Minimal background required: Calculus, differential equations and Fourier transform theory. Electrodynamics and field calculations or a similar course on electrodynamics or optics is recommended.

**Literature**
Detailed lecture notes as well as the presentation slides can be downloaded from the IPQ lecture pages. Additional reading:
- Hecht, E.: Optics, 2. Ed. Reading: Addison-Wesley 1974
Further textbooks in German (also in electronic form) can be named on request.

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies.
Module: Advanced Optical Materials (6) [M-PHYS-102196]

Responsibility: Martin Wegener

Organisation: KIT-Fakultät für Physik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices

Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-PHYS-102280 Advanced Optical Materials 6 Martin Wegener

Learning Control / Examinations

Type of Examination: Written examination
Duration of Examination: 120 Minutes
Modality of Exam: The written examination is scheduled for the beginning of the semester break after the end of the winter term.

Conditions
None

Content
I. Introduction (Maxwell’s equations, phenomenological material models, principles of optical waveguiding)
II. Photonic Crystals (Photonic bandstructures, 1D-, 2D-, 3D- photonic crystals, Defects, Numerical Methods, Photonic crystal fibers)
III. Plasmonics (Surface Plasmons, Metallic nanoparticles, optical Antennas, plasmon waveguides)
IV. Metamaterials (Negative index materials, transformation optics, microwave and photonic metamaterials, 3D metamaterials)
V. Integrated Optical Circuits (optical waveguides, nonlinear optical materials, tunable optical devices)

Recommendations
Basic background in physics, solid background in optics and photonics.

Literature

Workload
total 180 h, hereof 60 h contact hours (45 h lecture, 15 h problems class), and 120 h homework and self-studies
Module: Research Project  [M-PHYS-102194]

Responsibility: Heinz Kalt
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Biomedical Photonics / Elective Modules
Specialization / Specialization - Optical Systems
Specialization / Specialization - Solar Energy / Elective Modules
Additional Achievements

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Compulsory

Identifier | Course               | ECTS | Responsibility
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T-PHYS-103632 | Research Project        | 4    | Heinz Kalt

Learning Control / Examinations
The date of the project work is to be fixed individually. The format can be:

- a 1.5 week block course in the semester break
- a consecutive work of 4h/week during the entire semester

A written report of about 10 pages (at the discretion of the supervisor) concludes the Research Project. The overall performance of the students will be graded. The mark and the allocated 4CP are optional part of the elective courses in the specialization direction.

Conditions
None.

Qualification Objectives
The Research Project augments the theoretical knowledge acquired in the elective lecture courses by application to hands-on research in the respective KSOP research area. Hereby the student will also explore possible topics for the subsequent master thesis. The students

- get in-depth insight into a special research topic
- get hands-on experience in experimental and/or theoretical techniques
- learn how to obtain and evaluate relevant scientific literature
- get first experience on how to plan and organize a research project
- learn how to write a scientific report has the possibility to explore a topic for her/his Master’s Thesis

Content
The 3rd semester Research Project is optional, but highly recommended for students not working in a KSOP institute as research assistants. Accordingly, the topics of the Research Projects are provided by the KSOP PIs on an individual basis. The projects are supposed to complement the set of elective lecture courses within the specialization area of the student. The topics of the Research Projects are constantly adapted to the current research within KSOP.

Recommendations
Basic background in optics and photonics.

Literature
Literature is provided by the supervisors of the individual projects.
Workload

Total 120 h, hereof 60 h contact hours (supervised research) and 60 h preparation of report and self-studies.
Module: Solid-State Optics, without Exercises (6) [M-PHYS-102408]

Responsibility: Michael Hetterich

Organisation: KIT-Fakultät für Physik

Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

ECTS
Recurrence: Each winter term
Duration: 1 term
Language: English
Version: 1

Identifier Course ECTS Responsibility
T-PHYS-104773 Solid-State Optics, without Exercises 6 Michael Hetterich

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 45 minutes
Modality of Exam: Appointments for the oral exam can be made individually with the lecturer.

Conditions
None

Qualification Objectives
The students
- know the basic interaction processes between light and matter and are familiar with the polariton concept
- can explain the optical properties of insulators, semiconductors (including quantum structures), and metals
- comprehend the concept of the dielectric function and can utilize it to calculate relevant optical quantities (reflectance etc.)
- are familiar with the classical Drude–Lorentz model and its implications for the optical properties of insulators and metals (e.g., resulting dispersion, longitudinal and transverse eigenfrequencies, Reststrahlen bands, plasma frequency, etc.)
- understand the relation between classical and quantum-mechanical models for the dielectric function (e.g., concerning the oscillator strength) as well as the importance of the Kramers–Kronig relations
- can explain near band-edge spectra (absorption, reflection, luminescence) of semiconductors and insulators based on the concepts of joint density of states, oscillator strength, as well as excitonic effects
- are familiar with experimental techniques for the measurement of optical functions like grating/prism monochromators, set-ups for absorption, reflectance and luminescence measurements, basics of ellipsometry, Fourier, Raman, and modulation spectroscopy
- understand the origin of different optical nonlinearities and high-excitation effects as well as their mathematical description
- know the most important nonlinear optical effects (e.g., second-harmonic generation, parametric amplification, etc.), the problems involved (e.g., phase matching, choice of materials) and can apply their knowledge
- comprehend the basics of group theory and can apply it to solid-state optics, e.g., for the derivation of optical selection rules
Content
Maxwell’s equations, refractive index, dispersion, dielectric function, extinction, absorption, reflection, continuity conditions at interfaces, anisotropic media and layered systems, Drude–Lorentz model, reststrahlen bands, Bloch states and band structure, perturbation theory of light–matter interaction, band to band transitions, joint density of states, van Hove singularities, phonon and exciton polaritons, plasmons, metals, semiconductor heterostructures, low-dimensional systems, group theory and selection rules, nonlinear optics, high-excitation effects in semiconductors, measurement of optical functions: Fourier spectroscopy, ellipsometry, modulation spectroscopy, photoluminescence, reflectometry, absorptivity.

Recommendations
Basic knowledge in solid-state physics, optics, electrodynamics, and quantum-mechanics, solid mathematical background.

Literature
C. Klingshirn: Semiconductor Optics (Springer)
H. Ibach and H. Lüth, Solid-State Physics

Workload
total 180 h, hereof 90 h contact hours (lectures), and 90 h recapitulation and self-studies
**Module: X-Ray Optics (Sp-XRO) [M-MACH-101920]**

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**Learning Control / Examinations**

- **Type of Examination:** oral exam
- **Duration of Examination:** 30 Minutes
- **Modality of Exam:** The oral exam is scheduled individually for the beginning of the break after the WS.

**Conditions**

- Not any.

**Qualification Objectives**

The students:

- know the importance of X-ray optics in science and material analysis
- can describe the basic phenomena of X-ray generation, propagation and detection
- can calculate the optical path X-rays will follow
- are familiar with different types of X-ray optics
- can decide what X-ray optical component is suited best for what application
- comprehend the concepts of refraction, reflection, diffraction and absorption and are aware of their importance in X-ray optics
- know the differences between ray tracing and wave propagation methods and can assess what method is applicable in what case
- conceive manufacturing methods of X-ray optics
- know how to characterize X-ray optical components

**Content**

I. Introduction: Application of X-ray optics  
II. X-ray generation  
III. Propagation of X-rays in matter  
IV. X-ray detection  
V. Types of X-ray optics: reflecting, refracting, diffracting, absorbing  
VI. Characteristics of X-ray optics  
VII. Methods to simulate X-ray optics (ray tracing, wave propagation)  
VIII. Manufacturing of X-ray optics
IX. Characterization of X-ray optics

**Recommendations**
Basic knowledge in optics.

**Literature**
A. Erko, M. Idir, Th. Krist and A. G. Michette (editors), Modern Developments in X-Ray and Neutron Optics
www.x-ray-optics.com

**Workload**
total 90 h, hereof 30 h contact hours (lecture), and 60 h recapitulation, homework and self-studies
Module: Plastic Electronics / Polymerelectronics [M-ETIT-100475]

Responsibility: Ulrich Lemmer

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Specialization / Specialization - Solar Energy / Elective Modules

Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100763 Plastic Electronics / Polymerelectronics 3 Ulrich Lemmer

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 20 min
Modality of Exam: Oral exam (20 minutes)

Conditions
None.

Qualification Objectives
To enquire during lecture.

Content

1. Introduction
2. Electronic Structure of organic (macro) molecules
3. Optical properties of organic semiconductors
4. electronic transport
5. Light emitting diodes
6. organic solid state lasers
7. Xerography
8. Photovoltaic cells
9. Organic field effect transistors
10. Organic electroluminescent displays
11. Device fabrication

Recommendations
None.

Literature
The corresponding documents are available online in the VAB (https://studium.kit.edu/)

Workload
total 90 h, hereof 30 h lecture, and 60 h recapitulation and self-studies

Optics & Photonics (M.Sc.)
Module Handbook, Date 10/06/2017, Winter term 17/18
Module: Advanced Inorganic Materials (Sp-AIM) [M-CHEMBIO-101901]

Responsibility: Claus Feldmann
Organisation: KIT-Fakultät für Chemie und Biowissenschaften
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Additional Achievements

ECTS Recurrence Duration Language Version
3 Each summer term 2 terms English 2

Compulsory

Identifier Course ECTS Responsibility
T-CHEMBIO-103591 Advanced Inorganic Materials 3

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 min
Modality of Exam: The oral exam is scheduled at the end of the semester.

Conditions
No formal prerequisite, but continuous presence in the lecture is strongly recommended. An overall amount of 50% of the problems given in the written exam has to be solved correctly.

Qualification Objectives
The students refresh and elaborate their knowledge on inorganic materials, materials chemistry as well as basic inorganic chemistry and solid state chemistry. This comprises fundamental aspects of the chemistry of the elements as well as state-of-the-art knowledge on the synthesis, structure, properties (including optical properties) and application (including luminescence) of inorganic functional materials.

The students
- get familiar with basic inorganic chemistry and solid state chemistry
- get familiar with concepts of describing crystal structures
- know how to characterize inorganic solid compounds and materials
- learn how to prepare inorganic compounds and solid materials
- understand general aspects of structure-property relations
- comprehend general concepts of solid state chemistry and inorganic functional materials
- are able to rationalize fundamental properties of inorganic materials
- know general trends in view of a technical application of advanced inorganic materials

Content
Selected aspects of modern functional inorganic materials, including:
- High-temperature ceramics and hard materials
- Color pigments – from Egyptian blue to 2D Bragg stacks
- Phosphors, luminescence, spectroscopy
- Fast ion conductors and high-power batteries
- Superconductors: metals, alloys, oxocuprates and current developments
- Porous networks: from zeolites to metalorganic frameworks (MOFs)
- Transparent conductive oxides and dye-sensitized solar cells
- Magnetic pigments: magnetic recording, superparamagnetism and magnetothermal therapy
- Modern thermoelectric materials
- Fullerenes and fibre-reinforced composite materials
• Nanomaterials: Quantum Dots, hollow spheres and nanotubes
  . . . and other examples of advanced functional materials

Recommendations
Basic knowledge in chemistry

Literature
Selected reviews (as given in the lecture).

Workload
total 90 h, hereof 30 h lecture, and 90 h recapitulation and self-studies
Module: Nano-Optics (6) [M-PHYS-102146]

Responsibility: Andreas Naber

Organisation: KIT-Fakultät für Physik

Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-PHYS-102282 Nano-Optics 6 Andreas Naber

Learning Control / Examinations
Type of Examination: Oral exam
Duration of Examination: 30 minutes
Modality of Exam: oral exam

Conditions
None

Qualification Objectives
The students
- improve their understanding of general principles in electrodynamics and optics
- have a deeper understanding of the theoretical background in optical imaging and its relation to phenomena on a nanoscale
- are familiar with conventional techniques in optical microscopy and make use of their knowledge for the understanding of nano-optical methods
- realize the necessity of completely new experimental concepts to overcome the constraints of classical microscopy in the exploration of optical phenomena beyond the diffraction limit
- understand the basics of different experimental approaches for optical imaging on a nanoscale
- are able to discuss pros and cons of these techniques for applications in different fields of physics and biology
- are aware of the importance of nano-optical methods for the elucidation of long-standing interdisciplinary issues

Content
The lecture gives an introduction to theory and instrumentation of advanced methods in optical microscopy. Emphasis is laid on far- and near-field optical techniques with an optical resolution capability on a 10- to 100-nm-scale which is well below the principal limit of classical microscopy. Applications from different scientific disciplines are discussed (e.g., nano-antennas, single-molecule detection, plasmon-polariton propagation on metal surfaces, imaging of biological cell compartments including membranes).

Recommendations
Solid mathematical background, basics of classical optics

Literature
Will be mentioned in the lecture.

Workload
total 180 h, hereof 60 h contact hours (45 h lecture, 15 h problems class) and 120 h homework and self-studies
Module: Quantum Optics [M-PHYS-103093]

Responsibility: Carsten Rockstuhl
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Optical Systems
Additional Achievements

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Compulsory

Identifier | Course | ECTS | Responsibility
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T-PHYS-106135 | Quantum Optics | 4 | Carsten Rockstuhl

Learning Control / Examinations
Type of Examination: Written or oral examination
Duration of Examination: 90 minutes (written), 30 minutes (oral)
Modality of Exam: There will be a written or an oral examination, depending on the number of participants. This will be settled after the end of the fourth lecture. The written examination lasts for 90 minutes and shall be written without any supporting documents. The oral examination will last for 30 minutes.

Conditions
A minimum amount of correct solutions of the exercises that are biweekly distributed. Details will be announced in the lecture.

Qualification Objectives
The students shall learn to appreciate that quantum optics has been a framework to understand properties of light, which can by no means described with a classical theory, shall learn how to apply various methods from quantum mechanics to specific situation of quantum optics in general and to the description of the light-matter-interaction in specific, shall learn that there are fascinating opportunities to study with micro- and nanooptical systems various quantum optical phenomena, and shall appreciate that even though much of the current research is done out of intellectual curiosity, there are many application perspectives that promise to have a notable impact to our daily life.

Content
- Quantization of the electromagnetic field
- Various quantum states of light fields: optical photon-number, coherent, squeezed, Schrödinger’s cat states
- Classical and quantum coherence theory: photon bunching and antibunching
- Quantum description of optical interferometry: Mach-Zehnder interferometer with photons
- General description of open quantum system: master equation, Heisenberg-Langevin, and stochastic approaches
- Optical test of quantum mechanics: Hong-Ou-Mandel, quantum eraser, and Bell’s theorem experiments
- Interaction of a single atom with a classical field and quantum field
- From Rabi model to Jaynes-Cummings model: the most simplest model to describe the light-matter interaction
- Quantum master equation approach: description of finite life time of atoms
- Weak and strong couplings (spontaneous emission, Purcell effect, resonance fluorescence, lasers, and Rabi oscillation)
- Interaction of an ensemble of atoms with a quantum field (Dicke and Tavis-Cummings models, and superradiance)
- Quantum optical applications (quantum cryptography, quantum teleportation, quantum metrology, etc.)

Recommendations
Solid mathematical background, good knowledge of classical electromagnetism and optics, very good knowledge of quantum mechanics, foremost: interest in doing theoretical work.
11.1 Specialization - Photonic Materials and Devices

**Literature**
C. Gerry and P. Knight, *Introductory Quantum Optics.*
M. O. Scully and M. S. Zubairy, *Quantum Optics.*
M. Fox, *Quantum Optics: An Introduction.*
D.F. Walls and G. J. Milburn, *Quantum Optics.*
W. Schleich, *Quantum Optics in Phase Space.*

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial), and 75 h homework and self-studies
Module: Advanced Lithography for Biophotonic & Optofluidic Applications  
[M-MACH-103126]

Responsibility: Timo Mappes
Organisation: Institut für Mikrostrukturtechnik
Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Optical Systems

Additional Achievements

Compulsory

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Identifier Course ECTS Responsibility

T-MACH-106206 Advanced Lithography for Biophotonic & Optofluidic Applications 3 Timo Mappes

Learning Control / Examinations

Type of Examination: oral exam
Duration of Examination: 20 Minutes
Modality of Exam: The oral exam is by appointment.

Conditions
None

Qualification Objectives

While fulfilling the learning targets, the students are familiar with the working principle of scanning electron microscopes and their similarity to electron beam lithography, including electron sources and machine types. They understand secondary effects and can develop solutions how to avoid those for lithography. They understand the working principle of focussed ion beam machines and their application in fabrication, preparation and (correlative) microscopy.

are familiar with the processes required for multi-photon-lithography in resist and glass as well as their application for (hybrid) optofluidic and biophotonics.

understand the physical effects in advanced immersion and next generation lithography, in particular EUV lithography know how to evaluate a new lithographical method and may elaborate on its probability to be introduced in mass fabrication. In particular, they have a good understanding of the challenges in microfabrication, including the strategies to avoid pattern defects like e.g. structure collapse

understand the applicative needs and technical production prerequisites for the generation of scaffolds to be used as tools for the study of cell clusters e.g. in biology and medicine

are familiar with the realization of optofluidic systems to be used for integrated sensing, light guiding and tailored particle fabrication

Content

This module is introducing the application of advanced lithographic patterning for applications in optofluidics and biophotonics. With an overview on typical applications of micro optical and nano photonic systems, the challenges of lithographic patterning for their fabrication are motivated. The fabrication chain for high-end structures covering is discussed, starting from electron beam machines and their similarities to scanning electron microscopes. The available and the perspective for new and novel processes of parallel and serial lithography are discussed. The working principles of lithography machines as well as their limitations are presented. Aspects for masked-based optical lithography and multi-photon lithography in a broad range of materials are elaborated on. The challenges for resolution enhancement with immersion lithography are discussed by a problem-based learning approach. Subsequently the numerous technological...
SPECIALIZATION

11.1 Specialization - Photonic Materials and Devices

(including source and beam-shaping) and economic implications of the introduction of extreme ultra violet (EUV) lithography are discussed. In order to consolidate the interrelations of the individual process steps, the micro fabrication of (hybrid) optofluidic and biophotonic systems are discussed in detail. The particular boundary conditions to enable the application of those systems in biology and medicine as well as in sensing and imaging are elaborated on.

Recommendations
Basic knowledge in physics.

Literature
ISBN 0849331803
References to journal publications during the lecture

Workload
total 90 h, hereof 30 contact hours (30 h lecture), and 60 h homework and self-studies
Module: Computational Photonics, without ext. Exercises [M-PHYS-103089]

Responsibility: Carsten Rockstuhl
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices, Specialization / Specialization - Optical Systems, Specialization / Specialization - Solar Energy / Elective Modules, Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-PHYS-106131 Computational Photonics, without ext. Exercises 4 Carsten Rockstuhl

Learning Control / Examinations
Type of Examination: Programming assignment and oral presentation
Duration of Examination: 30 Minutes
Modality of Exam: One month before the end of the lecture period we distribute selected programming task from the field of computational photonics, which we ask you to solve at home. You will be fully prepared in the labwork course to solve those tasks. The examination then consists of an oral presentation at the end of the lecture period. There, you shall discuss the mathematical and physical background, shall outline implementation details and strategies for the problem you was assigned to, and shall present the results of a computation. You should also do a live simulation demonstration to convince your colleagues and us that the program was property implemented.

Conditions
None.

Qualification Objectives
The students shall learn how to use a computer to solve optical problems and how to visualize details of light-matter-interaction to obtain unprecedented insights, shall appreciate different strategies used to solve Maxwell’s equations, shall understand how spatial symmetries and the arrangement of matter in space can be used to formulate Maxwell’s equations such that they are amenable for a numerical solution, shall be able to implement programs by themselves at the end of the course which they can use in their on-going studies, shall learn how to use a computer to discuss and to explore physical phenomena in general and optical in specific, and shall be familiar with basic computational strategies that emerge in photonics, but comparably in any other scientific discipline.

Content
Transfer Matrix Method to describe the optical response from stratified media, Finite Differences to characterize eigenmode in fiber waveguides, Beam propagation method to describe the evolution of light in the realm of integrated optics, Grating methods to predict reflection and transmission from periodically arranged material in 1D and 2D, Mie Theory to describe the scattering of light from individual cylindrical or spherical objects, Finite-Difference Time-Domain method as a general purpose tool to solve micro- and nanooptical problems, Multiple Multipole Method as an approach to describe light scattering from single objects with an arbitrary shape, Greens’ Methods to discuss equally the scattering from single objects but embedded in an inhomogeneous background, Boundary Integral Method to discuss scattering from objects highly efficient using expressions for the fields on the surface.

Recommendations
Solid mathematical background, good knowledge of classical electromagnetism and optics, exposure to basic aspects of computational physics, foremost: interest in doing work numerically.
11.1 Specialization - Photonic Materials and Devices

**Literature**

“Classical Electrodynamics” John David Jackson,
“Theoretical Optics: An Introduction” Hartmann Römer,
“Principles of Optics” M. Born and E. Wolf,
“Computational Electro-magnetics: The Finite-Difference Time Domain Method,” A. Taflov and S. C. Hagness,
“Light Scattering by Small Particles”, H. C. van de Hulst.

**Workload**

total 120 h, hereof 45 h contact hours, (30 h lecture, 15 h labwork class), and 75 h homework and self-studies
Module: Optical Networks and Systems  [M-ETIT-103270]

Responsibility: Sebastian Randel

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices

Specialization / Specialization - Optical Systems

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<td>4</td>
<td>Each winter term</td>
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Identifier Course ECTS Responsibility

| T-ETIT-106506 | Optical Networks and Systems | 4 | Sebastian Randel |

Learning Control / Examinations

Type of Examination: oral exam
Duration of Examination: 20 min
Modality of Exam: Oral exams (20 minutes) are offered throughout the year upon individual appointment.

Conditions
There are no prerequisites for participating in the examination.

Qualification Objectives
The module provides knowledge about optical networks and systems with applications ranging from photonic interconnects, to fiber-to-the-home (FTTH), optical metro and long-haul networks, and automotive and industrial automation. The role of various network layers will be discussed in conjunction with relevant standards and protocols. Physical-layer specifications of relevant photonic components and system design trade-offs will be introduced.

The students

- get familiar with optical network architectures and protocols
- learn how to design optical communication systems in a variety of application scenarios
- understand how application constraints (performance, cost, energy-efficiency) drive technology innovation
- comprehend the benefits and challenges of using optical communication compared to alternatives (e.g. electrical, and wireless)
- are familiar with relevant standardization bodies and are able to interpret essential aspects of standard documents.

Content

Photonic interconnects: rack-to-rack, board-to-board, chip-to-chip, datacenter interconnects, intensity modulation, direct detection, single-mode fiber vs. multi-mode fiber, serial vs. parallel optics, space-division multiplexing vs. wavelength-division multiplexing, Ethernet (10G, 40G, 100G), Fibre Channel, scaling and energy efficiency.

Access networks: fiber-to-the-X, passive optical networks (GPON, EPON, NG-PON2, WDM PON), statistical multiplexing vs. point-to-point

Metro- and long-haul networks:

- System-design aspects: dense WDM (ITU grid), optical amplifiers, chromatic dispersion, coherent detection, optical vs. electronic impairment mitigation, capacity limits.
- Wavelength switching: wavelength selective switch (WSS), reconfigurable optical add-drop multiplexer (ROADM).
- Standards and protocols: synchronous optical networking and synchronous digital hierarchy (SONET/SDH), optical transport network (OTN), generalized multi-protocol label switching (GMPLS), software-defined networking (SDN).

Optical networks in automotive and industrial automation: polymer-optical fiber (POF), MOST Bus, Profibus and Profinet, optical vs. electrical communication links, overcoming bandwidth limitations using digital signal processing.
Recommendations
Interest in communications engineering, networking, and photonics

Literature
Ivan Kaminow, Tingye Li, Alan E. Willner (Editors), Optical Fiber Telecommunications (Sixth Edition), Elsevier
Rajiv Ramaswami, Kumar N. Sivarajan and Galen H. Sasaki, Optical Networks (Third Edition), Elsevier

Workload
total 120 h, hereof 30 h lecture, 15 h problems class and 75 h recapitulation and self-studies
11.2 Specialization - Advanced Spectroscopy

Module: Laser Physics [M-ETIT-100435]

Responsibility: Christian Koos

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Biomedical Photonics / Elective Modules
Specialization / Specialization - Optical Systems
Additional Achievements

ECTS 4

Recurrence Each winter term

Duration 1 term

Language English

Version 1

Compulsory

Identifier T-ETIT-100741

Course Laser Physics

ECTS 4

Responsibility Christian Koos

Learning Control / Examinations

Type of Examination: Oral examination
Duration of Examination: 30 minutes
Modality of Exam: The oral exam is scheduled for the beginning of the break after the WS.

Conditions
No formal prerequisites. However, steady participation in lecture and tutorial as well as thorough preparation based on the scriptum is highly recommended.

Qualification Objectives

The students

- know the fundamental relations and background of lasers
- gain the necessary knowledge for understanding and dimensioning of lasers, laser media, optical resonators and pump strategies
- understand the pulse generation with lasers and their fundamental relations
- obtain the necessary knowledge on several lasers; gas-, solid state, fiber- and disc-lasers in the visible and middle infrared range

Content
1 Quantum-mechanical fundamentals of lasers
1.1 Einstein relations and Planck’s law
1.2 Transition probabilities and matrix elements
1.3 Mode structure of space and the origin of spontaneous emission
1.4 Cross sections and broadening of spectral lines
2 The laser principles
2.1 Population in version and feedback
2.2 Spectroscopic laser rate equations
2.3 Potential model of the laser
3 Optical Resonators
3.1 Linear resonators and stability criterion
3.2 Mode structure and intensity distribution
3.3 Line width of the laser emission
4 Generation of short and ultra-short pulses
4.1 Basics of Q-switching
4.2 Basics of mode locking and ultra-short pulses
5 Laser examples and their applications
5.1 Gas lasers: The Helium-Neon-Laser
5.2 Solid-state lasers
5.2.1 The Nd3+-Laser
5.2.2 The Tm3+-Laser
5.2.3 The Ti3+:Al2O3 Laser
5.3 Special realisations of lasers
5.3.1 Thermal lensing and thermal stress
5.3.2 The fiber laser
5.3.3 The thin-dis laser

Recommendations
Solid mathematical background, basic knowledge in physics

Literature
M. Eichhorn, Laser physics (Springer)
M. Eichhorn, Laserphysik (Springer)
A. E. Siegman, Lasers (University Science Books)
B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics (Wiley-Interscience)
F. K. Kneubühl, M. W. Sigrist, Laser (Teubner)

Workload
total 120 h, hereof 45 h contact hours (30 h lectures, 15 h tutorial) and 75 h recapitulation and self-studies
Module: Laser Metrology [M-ETIT-100434]

Responsibility: Christian Koos

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular An-chorage: Compulsory Elective

Contained in: Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Optical Systems

ECTS

Recurrence Duration Language Version
3 Each summer term 1 term English 1

Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100643 Laser Metrology 3 Christian Koos

Learning Control / Examinations
Type of Examination: Oral examination
Duration of Examination: 30 minutes
Modality of Exam: The oral exam is scheduled for the beginning of the break after the SS

Conditions
No formal prerequisites. However, steady participation in the lecture as well as thorough preparation based on the scriptum is highly recommended.

Qualification Objectives
The students
- know the fundamental properties of laser light
- comprehend the different information accessible by laser metrology
- understand the fundamentals of different detectors and their limits for beam diagnostics
- comprehend several laser-metrological setups: Moiré, range and velocity measurements, absorption and scattering techniques.

Content
1. Laser diagnostics - theoretical considerations (laser beam properties, coherence, spectral emission of lasers, mode structure and selection, coherence length)
2. Metrological accessible information (propagation in homogeneous and isotropic, in inhomogeneous and in anisotropic media)
3. Beam diagnostics (photoelectric detectors, information theory, granulation properties of laser light)
4. Laser-Interferometer (fundamentals, two-beam Interferometer, interferometry applications in plasma physics, two- and multiwavelength-interferometry, laser gyroscopes)
5. Moiré technique (Moiré deflectometry, Fresnel- and Fraunhofer diffraction, applications and evaluation of the Moiré technique)
6. Laser range measurements (fundamentals, atmospheric influence on propagation, optical distance measurement techniques, accuracy, sensitivity, heterodyne detection, selected heterodyne detection schemes, tomoscopy)
7. Laser velocity measurement techniques (Doppler principle, measuring flow velocities using Doppler effect, the two-focus technique or laser anemometry; time-resolved imaging particle-trace anemometry)
8. Absorption and scattering techniques (absorption techniques, LIDARs, scattering processes in laser diagnostics, spontaneous scattering techniques, spectroscopic techniques, stimulated scattering, nonlinear optical laser light scattering techniques)
**Recommendations**
Solid mathematical background, basic knowledge in physics

**Literature**
M. Eichhorn, *Laser metrology* - Scriptum

**Workload**
total 90 h, hereof 30 h contact hours (30 h lectures) and 60 h recapitulation and self-studies
Module: Nano-Optics (6) [M-PHYS-102146]

Responsibility: Andreas Naber

Organisation: KIT-Fakultät für Physik

Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Solar Energy / Elective Modules

Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-PHYS-102282 Nano-Optics 6 Andreas Naber

Learning Control / Examinations

Type of Examination: Oral exam
Duration of Examination: 30 minutes
Modality of Exam: oral exam

Conditions
None

Qualification Objectives

The students
- improve their understanding of general principles in electrodynamics and optics
- have a deeper understanding of the theoretical background in optical imaging and its relation to phenomena on a nanoscale
- are familiar with conventional techniques in optical microscopy and make use of their knowledge for the understanding of nano-optical methods
- realize the necessity of completely new experimental concepts to overcome the constraints of classical microscopy in the exploration of optical phenomena beyond the diffraction limit
- understand the basics of different experimental approaches for optical imaging on a nanoscale
- are able to discuss pros and cons of these techniques for applications in different fields of physics and biology
- are aware of the importance of nano-optical methods for the elucidation of long-standing interdisciplinary issues

Content

The lecture gives an introduction to theory and instrumentation of advanced methods in optical microscopy. Emphasis is laid on far- and near-field optical techniques with an optical resolution capability on a 10- to 100-nm-scale which is well below the principal limit of classical microscopy. Applications from different scientific disciplines are discussed (e.g., nano-antennas, single-molecule detection, plasmon-polariton propagation on metal surfaces, imaging of biological cell compartments including membranes).

Recommendations

Solid mathematical background, basics of classical optics

Literature

Will be mentioned in the lecture.

Workload

total 180 h, hereof 60 h contact hours (45 h lecture, 15 h problems class) and 120 h homework and self-studies
Module: Research Project [M-PHYS-102194]

Responsibility: Heinz Kalt

Organisation: KIT-Fakultät für Physik

Curricular Anchorage:

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Optical Systems
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

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Learning Control / Examinations
The date of the project work is to be fixed individually. The format can be:

- a 1.5 week block course in the semester break
- a consecutive work of 4h/week during the entire semester

A written report of about 10 pages (at the discretion of the supervisor) concludes the Research Project. The overall performance of the students will be graded. The mark and the allocated 4CP are optional part of the elective courses in the specialization direction.

Conditions
None.

Qualification Objectives
The Research Project augments the theoretical knowledge acquired in the elective lecture courses by application to hands-on research in the respective KSOP research area. Hereby the student will also explore possible topics for the subsequent master thesis.
The students

- get in-depth insight into a special research topic
- get hands-on experience in experimental and/or theoretical techniques
- learn how to obtain and evaluate relevant scientific literature
- get first experience on how to plan and organize a research project
- learn how to write a scientific report has the possibility to explore a topic for her/his Master’s Thesis

Content
The 3rd semester Research Project is optional, but highly recommended for students not working in a KSOP institute as research assistants. Accordingly, the topics of the Research Projects are provided by the KSOP PIs on an individual basis. The projects are supposed to complement the set of elective lecture courses within the specialization area of the student. The topics of the Research Projects are constantly adapted to the current research within KSOP.

Recommendations
Basic background in optics and photonics.

Literature
Literature is provided by the supervisors of the individual projects.
Workload
total 120 h, hereof 60 h contact hours (supervised research) and 60 h preparation of report and self-studies
**Module: Solid-State Optics, without Exercises (6) [M-PHYS-102408]**

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<th>Michael Hetterich</th>
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|                                 | Specialization / Specialization - Advanced Spectroscopy  
|                                 | Specialization / Specialization - Solar Energy / Elective Modules  
|                                 | Additional Achievements |

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<td>Solid-State Optics, without Exercises</td>
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<td>Michael Hetterich</td>
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**Learning Control / Examinations**

Type of Examination: oral exam  
Duration of Examination: 45 minutes  
Modality of Exam: Appointments for the oral exam can be made individually with the lecturer.

**Conditions**

None

**Qualification Objectives**

The students

- know the basic interaction processes between light and matter and are familiar with the polariton concept
- can explain the optical properties of insulators, semiconductors (including quantum structures), and metals
- comprehend the concept of the dielectric function and can utilize it to calculate relevant optical quantities (reflectance etc.)
- are familiar with the classical Drude–Lorentz model and its implications for the optical properties of insulators and metals (e.g., resulting dispersion, longitudinal and transverse eigenfrequencies, Reststrahlen bands, plasma frequency, etc.)
- understand the relation between classical and quantum-mechanical models for the dielectric function (e.g., concerning the oscillator strength) as well as the importance of the Kramers–Kronig relations
- can explain near band-edge spectra (absorption, reflection, luminescence) of semiconductors and insulators based on the concepts of joint density of states, oscillator strength, as well as excitonic effects
- are familiar with experimental techniques for the measurement of optical functions like grating/prism monochromators, set-ups for absorption, reflectance and luminescence measurements, basics of ellipsometry, Fourier, Raman, and modulation spectroscopy
- understand the origin of different optical nonlinearities and high-excitation effects as well as their mathematical description
- know the most important nonlinear optical effects (e.g., second-harmonic generation, parametric amplification, etc.), the problems involved (e.g., phase matching, choice of materials) and can apply their knowledge
- comprehend the basics of group theory and can apply it to solid-state optics, e.g., for the derivation of optical selection rules
Content
Maxwell’s equations, refractive index, dispersion, dielectric function, extinction, absorption, reflection, continuity conditions at interfaces, anisotropic media and layered systems, Drude–Lorentz model, reststrahlen bands, Bloch states and band structure, perturbation theory of light–matter interaction, band to band transitions, joint density of states, van Hove singularities, phonon and exciton polaritons, plasmons, metals, semiconductor heterostructures, low-dimensional systems, group theory and selection rules, nonlinear optics, high-excitation effects in semiconductors, measurement of optical functions: Fourier spectroscopy, ellipsometry, modulation spectroscopy, photoluminescence, reflectometry, absorptivity.

Recommendations
Basic knowledge in solid-state physics, optics, electrodynamics, and quantum-mechanics, solid mathematical background.

Literature
C. Klingshirn: Semiconductor Optics (Springer)
H. Ibach and H. Lüth, Solid-State Physics

Workload
total 180 h, hereof 90 h contact hours (lectures), and 90 h recapitulation and self-studies
Module: Advanced Inorganic Materials (Sp-AIM) [M-CHEMBIO-101901]

Responsibility: Claus Feldmann

Organisation: KIT-Fakultät für Chemie und Biowissenschaften

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
              Specialization / Specialization - Advanced Spectroscopy
              Additional Achievements

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<td>3</td>
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Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 min
Modality of Exam: The oral exam is scheduled at the end of the semester.

Conditions
No formal prerequisite, but continuous presence in the lecture is strongly recommended. An overall amount of 50% of the problems given in the written exam has to be solved correctly.

Qualification Objectives
The students refresh and elaborate their knowledge on inorganic materials, materials chemistry as well as basic inorganic chemistry and solid state chemistry. This comprises fundamental aspects of the chemistry of the elements as well as state-of-the-art knowledge on the synthesis, structure, properties (including optical properties) and application (including luminescence) of inorganic functional materials.

The students
• get familiar with basic inorganic chemistry and solid state chemistry
• get familiar with concepts of describing crystal structures
• know how to characterize inorganic solid compounds and materials
• learn how to prepare inorganic compounds and solid materials
• understand general aspects of structure-property relations
• comprehend general concepts of solid state chemistry and inorganic functional materials
• are able to rationalize fundamental properties of inorganic materials
• know general trends in view of a technical application of advanced inorganic materials

Content
Selected aspects of modern functional inorganic materials, including:
• High-temperature ceramics and hard materials
• Color pigments – from Egyptian blue to 2D Bragg stacks
• Phosphors, luminescence, spectroscopy
• Fast ion conductors and high-power batteries
• Superconductors: metals, alloys, oxocuprates and current developments
• Porous networks: from zeolites to metalorganic frameworks (MOFs)
• Transparent conductive oxides and dye-sensitized solar cells
• Magnetic pigments: magnetic recording, superparamagnetism and magnetothermal therapy
• Modern thermoelectric materials
• Fullerenes and fibre-reinforced composite materials
• Nanomaterials: Quantum Dots, hollow spheres and nanotubes
  ... and other examples of advanced functional materials

**Recommendations**
Basic knowledge in chemistry

**Literature**
Selected reviews (as given in the lecture).

**Workload**
total 90 h, hereof 30 h lecture, and 90 h recapitulation and self-studies
Module: Molecular Spectroscopy (Sp-MS) [M-CHEMBIO-101902]

Responsibility: Manfred Kappes, Andreas-Neil Unterreiner

Organisation: KIT-Fakultät für Chemie und Biowissenschaften

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Advanced Spectroscopy

Additional Achievements

ECTS Recurrence Duration Language Version
4 Once 1 term English 1

Compulsory

Identifier Course ECTS Responsibility
T-CHEMBIO-101864 Molecular Spectroscopy 4

Learning Control / Examinations
Type of Examination: written exam
Duration of Examination: 120 Minutes

Modality of Exam: The written exam is scheduled for the beginning of the break after the WS. A resit exam is offered at the end of the break. The exam consists of a set of problems that the students solve with the aid of certain allowed resources.

Conditions
One page of exercises is handed out to the students as homework each week. Solutions to these exercises can be presented by the students during exercises/tutorials on the blackboard on a voluntary basis. Participation in questions and answers during tutorials is strongly supported and encouraged (though not a formal requirement).

Qualification Objectives
Students will obtain a comprehensive overview of the field of molecular spectroscopy and will learn to interpret and assign molecular spectra. Starting with the quantum mechanical foundations of light-matter interactions, selection rules and structure-dependent transition energies will be derived for rotational-, vibrational- and electronic-spectroscopy. The focus is on dipole-allowed transitions in diatomic molecules. However, students will also learn about absorption/emission in small polyatomic species. Additionally, the fundamentals of Raman scattering as well as nuclear and electron spin resonance spectroscopy will be presented.

The students
• understand and can apply the quantum mechanical description of molecular rotational, vibrational and electronic spectroscopy;
• can analyse and assign microwave, vibrational, electronic and Raman spectra of diatomic and small polyatomic molecules;
• understand the interdependence between spectroscopic method, experimental design and required optical components
• learn the fundamentals of electron and nuclear spin resonance spectroscopy

Content
I. Spectroscopic fundamentals: spectral regions; conversion factors; resolution; characteristic timescales; light-matter interactions; experimental configurations;
II. Quantum-mechanical treatment of light absorption: Schrödinger equation; time-dependent perturbation theory description of transitions in a two-level system; Einstein coefficients; line profiles (lifetime broadening, Doppler- and collisional broadening); saturation;
III. Diatomic molecules: transition dipole moment formalism to calculate selection rules for harmonic oscillator and rigid rotor models, occupation numbers and transition strengths, Morse potential and Pekeris equation, vibration-rotation spectroscopy; vibrational overtones and time-independent perturbation theory; Raman effect and quantum-mechanical description; couplings and complications (nuclear spin statistics, quadratic Stark effect, rotational Zeeman effect);
IV. Polyatomic molecules: rotation in classical mechanics (moment of inertia tensor; oblate and prolate rotors; asymmet-
ric rotor); quantum-mechanical description; selection rules and correlations between symmetric and asymmetric rotors; structure determination by microwave spectroscopy; vibrations in polyatomics; degrees of freedom; Lagrangian mechanics; normal coordinates and symmetry; selection rules; GF-matrix formalism for normal coordinate analysis;

V. Introduction to electronic spectroscopy: Born-Oppenheimer approximation; Franck-Condon factors;
VI. Introduction to electron and nuclear spin resonance: basic theory and experimental setups

Recommendations
Basic atomic/molecular quantum mechanics, Important: indicate your intention to take this module in English by emailing the lecturer before semester begin

Literature
Atkins: Molecular Quantum Mechanics, P. Bernath: Spectra of Atoms and Molecules, Demtröder: Laser Spectroscopy

Workload
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies
Module: Quantum Optics [M-PHYS-103093]

Responsibility: Carsten Rockstuhl
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Optical Systems
Additional Achievements

ECTS 4
Recurrence Irregular
Duration 1 term
Language English
Version 1

Compulsory

Identifier Course ECTS Responsibility
T-PHYS-106135 Quantum Optics 4 Carsten Rockstuhl

Learning Control / Examinations
Type of Examination: Written or oral examination
Duration of Examination: 90 minutes (written), 30 minutes (oral)
Modality of Exam: There will be a written or an oral examination, depending on the number of participants. This will be settled after the end of the fourth lecture. The written examination lasts for 90 minutes and shall be written without any supporting documents. The oral examination will last for 30 minutes.

Conditions
A minimum amount of correct solutions of the exercises that are biweekly distributed. Details will be announced in the lecture.

Qualification Objectives
The students shall learn to appreciate that quantum optics has been a framework to understand properties of light, which can by no means described with a classical theory, shall learn how to apply various methods from quantum mechanics to specific situation of quantum optics in general and to the description of the light-matter-interaction in specific, shall learn that there are fascinating opportunities to study with micro- and nano-optical systems various quantum optical phenomena, and shall appreciate that even though much of the current research is done out of intellectual curiosity, there are many application perspectives that promise to have a notable impact to our daily life.

Content
- Quantization of the electromagnetic field
- Various quantum states of light fields: optical photon-number, coherent, squeezed, Schrödinger’s cat states
- Classical and quantum coherence theory: photon bunching and antibunching
- Quantum description of optical interferometry: Mach-Zehnder interferometer with photons
- General description of open quantum system: master equation, Heisenberg-Langevin, and stochastic approaches
- Optical test of quantum mechanics: Hong-Ou-Mandel, quantum eraser, and Bell’s theorem experiments
- Interaction of a single atom with a classical field and quantum field
- From Rabi model to Jaynes-Cummings model: the most simplest model to describe the light-matter interaction
- Quantum master equation approach: description of finite life time of atoms
- Weak and strong couplings (spontaneous emission, Purcell effect, resonance fluorescence, lasers, and Rabi oscillation)
- Interaction of an ensemble of atoms with a quantum field (Dicke and Tavis-Cummings models, and superradiance)
- Quantum optical applications (quantum cryptography, quantum teleportation, quantum metrology, etc.)

Recommendations
Solid mathematical background, good knowledge of classical electromagnetism and optics, very good knowledge of quantum mechanics, foremost: interest in doing theoretical work
Literature
C. Gerry and P. Knight, *Introductory Quantum Optics*.
M. O. Scully and M. S. Zubairy, *Quantum Optics*.
M. Fox, *Quantum Optics: An Introduction*.
R. Loudon, *The Quantum Theory of Light*.
D.F. Walls and G. J. Milburn, *Quantum Optics*.
W. Schleich, *Quantum Optics in Phase Space*.

Workload
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial), and 75 h homework and self-studies
Module: Adaptive Optics [M-ETIT-103802]

Responsibility: Ulrich Lemmer

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Optical Systems

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-107644 Adaptive Optics 3 Ulrich Lemmer

Learning Control / Examinations
Type of Examination: Oral examination
Duration of Examination: 30 Minutes
Modality of Exam: The oral exam is scheduled two weeks after WS.

Qualification Objectives
Course Description
Adaptive optics is a technology of correcting the effect of atmospheric turbulence on images of space objects and on laser beams propagating through random and highly aberrated media such as turbulence, tissue, and the inside of the human eye, to name just a few applications. The course will familiarize the students with theoretical basics of light propagation through random media, principles of wavefront sensing and reconstruction, as well as wavefront correction with deformable mirrors.

The students will also receive solid introduction to statistical optics, the Kolmogorov theory of turbulence, practical aspects of turbulence simulation and modelling of adaptive optics performance. Design of adaptive optics systems through error budget equations, simulations and analytical models will be discussed. Applications from astronomy, free-space laser communications and medicine will be given.

Learning targets
The students will:
- get familiar with Fourier description of imaging through aberrated optical systems and random media,
- understand the description of aberrations through Zernike modes,
- learn how to analytically compute the effects of turbulence on various optical observables such as image/beam motion, temporal power spectra, Zernike modes, scintillation, etc.,
- understand the effect of noise on various quantities and metrics pertinent to the design of adaptive optical systems,
- understand the advantages and disadvantages of various schemes for wavefront sensing and correction,
- learn how to simulate and design simple adaptive optics systems.

Content
1. Theory of turbulence
2. Fourier optics
3. Statistical optics
4. Sources and description of aberrations
5. Adaptive optics systems
6. Wavefront sensing
7. Wavefront correction
8. Simulation of adaptive optical systems

Recommendations
Fourier analysis, statistics, classical optics, probability theory

Literature
Michael C. Roggemann, Byron M. Welsh, Imaging through Turbulence, CRC Press

Workload
total 90 h, hereof 30 h contact hours and 60 h homework and self-studies
11.3 Specialization - Biomedical Photonics

11.3.1 Compulsory Modules

**Module: Advanced Molecular Cell Biology (Sp-AMCB) [M-CHEMBIO-101904]**

**Responsibility:** Martin Bastmeyer, Franco Weth

**Organisation:** KIT-Fakultät für Chemie und Biowissenschaften

**Curricular Anchorage:** Compulsory Elective

**Contained in:** Specialization / Specialization - Biomedical Photonics / Compulsory Modules

**Additional Achievements**

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**Learning Control / Examinations**

Type of Examination: Oral or written

Duration of Examination: 45 min (oral) or 120 min (written)

Modality of Exam: The exam will be oral or written depending on the number of course participants. The exact modality of the exam will be announced at the beginning of the semester. The exam is scheduled for the break after the WS. A resit exam will be offered when needed.

**Conditions**

Advanced textbook or review articles will be announced on a weekly basis. They have to be read by all participants. The contents will be discussed in the class sessions. Each class session is chaired by one participant and all participants have to contribute a sub-chapter/figure per session. For the problems class, exercise sheets will be handed out and participants have to be prepared to present their solutions.

**Qualification Objectives**

The students

- are able to extract the central ideas from an advanced textbook or review article and introduce their fellow student to the topic,
- have acquire an advanced knowledge of the cell division cycle and exemplify applications of FRET for its analysis,
- understand DNA replication, recombination and repair and the basis of fluorescence based deep sequencing,
- are familiar with nuclear organization and epigenetic regulation and FISH as a means of analysing chromosomes,
- understand protein folding and degradation and discuss optical tweezers as a tool for the investigation of the folding problem,
- can address posttranslational modifications and cutting edge technologies based on fluorophore click-chemistry to observe them,
- comprehend cell suicide (apoptosis) and techniques of laser ablation to induce cell death
- are familiar with the different forms of cell/cell and cell/matrix contacts and with TIRF microscopy as a means of studying them,
- conceive the mechanisms of cell migration and their observation by live cell imaging,
- are familiar with principal mechanisms of embryonic development and understand fluorescent microarray technology for profiling the accompanying gene expression changes,
- understand the concepts of tissues, stem cells and cancer and of the quantification of gene expression by fluorescent nanostring and real-time fluorescence spectroscopy (qPCR),
- understand excitability and synaptic transmission in neurons and their observation with voltage and calcium sensitive
fluorophores,
• are acquainted with the concepts of immunity and the application of antibodies in fluorescent immunoassays.

Content
Progress in no other field of science is so intimately linked to the continuing development and welfare of humanity as the achievements of the life sciences. Modern biomedical research, however, is inconceivable without cutting-edge Optics & Photonics technologies ranging from high-throughput sequencing to super-resolution microscopy. Most students of Optics & Photonics are therefore likely to get in contact with life scientists during their careers. In this course, they will prepare themselves for fruitful future collaborations, which rely on shared concepts and terminologies. To this end, students will familiarize themselves with the basic principles and ideas of Molecular Cell Biology, which is at the heart of modern Biosciences.

I. Introduction to the cell
II. Concepts from Organic Chemistry pertinent to the Life Sciences
III. Concepts from Physical Chemistry pertinent to the Life Sciences
IV. Nucleic acids and proteins
V. Gene expression
VI. Methods
VII. Genomic variability and evolution
VIII. Cell membranes
IX. Energy metabolism
X. Cell signalling
XI. Cell compartments
XII. Cytoskeleton and cell division

Recommendations
Passed exam of the Adjustment Course in “Basic Molecular Cell Biology”

Literature

Workload
Total 150 h, hereof 40 h contact hours (30 h class, 10 h problem class), and 110 h homework and self-studies
11.3.2 Elective Modules

Module: Laser Physics  [M-ETIT-100435]

Responsibility: Christian Koos
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Biomedical Photonics / Elective Modules
Specialization / Specialization - Optical Systems
Additional Achievements

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Identifier Course ECTS Responsibility
T-ETIT-100741 Laser Physics 4 Christian Koos

Learning Control / Examinations
Type of Examination: Oral examination
Duration of Examination: 30 minutes
Modality of Exam: The oral exam is scheduled for the beginning of the break after the WS.

Conditions
No formal prerequisites. However, steady participation in lecture and tutorial as well as thorough preparation based on the scriptum is highly recommended.

Qualification Objectives
The students

- know the fundamental relations and background of lasers
- gain the necessary knowledge for understanding and dimensioning of lasers, laser media, optical resonators and pump strategies
- understand the pulse generation with lasers and their fundamental relations
- obtain the necessary knowledge on several lasers; gas-, solid state, fiber- and disc-lasers in the visible and middle infrared range

Content
1 Quantum-mechanical fundamentals of lasers
1.1 Einstein relations and Planck’s law
1.2 Transition probabilities and matrix elements
1.3 Mode structure of space and the origin of spontaneous emission
1.4 Cross sections and broadening of spectral lines
2 The laser principles
2.1 Population in version and feedback
2.2 Spectroscopic laser rate equations
2.3 Potential model of the laser
3 Optical Resonators
3.1 Linear resonators and stability criterion
3.2 Mode structure and intensity distribution
3.3 Line width of the laser emission
4 Generation of short and ultra-short pulses
4.1 Basics of Q-switching
4.2 Basics of mode locking and ultra-short pulses
5 Laser examples and their applications
5.1 Gas lasers: The Helium-Neon-Laser
5.2 Solid-state lasers
5.2.1 The Nd3+-Laser
5.2.2 The Tm3+-Laser
5.2.3 The Ti3+:Al2O3 Laser
5.3 Special realisations of lasers
5.3.1 Thermal lensing and thermal stress
5.3.2 The fiber laser
5.3.3 The thin-dis laser

Recommendations
Solid mathematical background, basic knowledge in physics

Literature
M. Eichhorn, Laser physics (Springer)
M. Eichhorn, Laserphysik (Springer)
A. E. Siegman, Lasers (University Science Books)
B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics (Wiley-Interscience)
F. K. Kneubühl, M. W. Sigrist, Laser (Teubner)

Workload
total 120 h, hereof 45 h contact hours (30 h lectures, 15 h tutorial) and 75 h recapitulation and self-studies
Module: Nano-Optics (6) [M-PHYS-102146]

Responsibility: Andreas Naber

Organisation: KIT-Fakultät für Physik

Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Solar Energy / Elective Modules

Additional Achievements

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Compulsory

Identifier | Course | ECTS | Responsibility
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T-PHYS-102282 | Nano-Optics | 6 | Andreas Naber

Learning Control / Examinations
- Type of Examination: Oral exam
- Duration of Examination: 30 minutes
- Modality of Exam: oral exam

Conditions
None

Qualification Objectives
The students
- improve their understanding of general principles in electrodynamics and optics
- have a deeper understanding of the theoretical background in optical imaging and its relation to phenomena on a nanoscale
- are familiar with conventional techniques in optical microscopy and make use of their knowledge for the understanding of nano-optical methods
- realize the necessity of completely new experimental concepts to overcome the constraints of classical microscopy in the exploration of optical phenomena beyond the diffraction limit
- understand the basics of different experimental approaches for optical imaging on a nanoscale
- are able to discuss pros and cons of these techniques for applications in different fields of physics and biology
- are aware of the importance of nano-optical methods for the elucidation of long-standing interdisciplinary issues

Content
The lecture gives an introduction to theory and instrumentation of advanced methods in optical microscopy. Emphasis is laid on far- and near-field optical techniques with an optical resolution capability on a 10- to 100-nm-scale which is well below the principal limit of classical microscopy. Applications from different scientific disciplines are discussed (e.g., nano-antennas, single-molecule detection, plasmon-polariton propagation on metal surfaces, imaging of biological cell compartments including membranes).

Recommendations
Solid mathematical background, basics of classical optics

Literature
Will be mentioned in the lecture.

Workload
Total 180 h, hereof 60 h contact hours (45 h lecture, 15 h problems class) and 120 h homework and self-studies
Module: Research Project [M-PHYS-102194]

Responsibility: Heinz Kalt
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
                  Specialization / Specialization - Advanced Spectroscopy
                  Specialization / Specialization - Biomedical Photonics / Elective Modules
                  Specialization / Specialization - Optical Systems
                  Specialization / Specialization - Solar Energy / Elective Modules
                  Additional Achievements

ECTS 4  Recurrence Each winter term  Duration 1 term  Language English  Version 1

Compulsory

Identifier Course ECTS Responsibility
T-PHYS-103632 Research Project 4 Heinz Kalt

Learning Control / Examinations
The date of the project work is to be fixed individually. The format can be:

- a 1.5 week block course in the semester break
- a consecutive work of 4h/week during the entire semester

A written report of about 10 pages (at the discretion of the supervisor) concludes the Research Project. The overall performance of the students will be graded. The mark and the allocated 4CP are optional part of the elective courses in the specialization direction.

Conditions
None.

Qualification Objectives
The Research Project augments the theoretical knowledge acquired in the elective lecture courses by application to hands-on research in the respective KSOP research area. Hereby the student will also explore possible topics for the subsequent master thesis.

The students
- get in-depth insight into a special research topic
- get hands-on experience in experimental and/or theoretical techniques
- learn how to obtain and evaluate relevant scientific literature
- get first experience on how to plan and organize a research project
- learn how to write a scientific report has the possibility to explore a topic for her/his Master’s Thesis

Content
The 3rd semester Research Project is optional, but highly recommended for students not working in a KSOP institute as research assistants. Accordingly, the topics of the Research Projects are provided by the KSOP PIs on an individual basis. The projects are supposed to complement the set of elective lecture courses within the specialization area of the student. The topics of the Research Projects are constantly adapted to the current research within KSOP.

Recommendations
Basic background in optics and photonics.

Literature
Literature is provided by the supervisors of the individual projects.
**Workload**

total 120 h, hereof 60 h contact hours (supervised research) and 60 h preparation of report and self-studies
Module: Organic Photochemistry (Sp-OPC) [M-CHEMBIO-101907]

Responsibility: Hans-Achim Wagenknecht

Organisation: KIT-Fakultät für Chemie und Biowissenschaften

Curricular Anchorage: Compulsory Elective

-contained in: Specialization / Specialization - Biomedical Photonics / Elective Modules Additional Achievements

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Compulsory

Identifier | Course | ECTS | Responsibility
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T-CHEMBIO-105195 | Organic Photochemistry | 3 | 

Learning Control / Examinations

Type of Examination: Oral exam
Duration of Examination: 30 min
Modality of Exam: The written exam is scheduled for the beginning of the break after the WS. A resit exam is offered at the end of the break.

Conditions
No formal prerequisite, but participation in the lecture is highly recommended.

Qualification Objectives

The students learn the principles of organic photochemistry. This includes the knowledge about the photochemical reactivity of functional groups in organic compounds, photocatalysis and applications in synthesis and bioorganic chemistry.

The students
- Can draw reaction mechanism of organic photochemical reactions
- Know the difference of direct excitation of organic functional groups vs. photocatalysis
- Know the photophysics of excitation of organic chromophores and the major decay pathways
- Can relate structure of functional groups to photochemical reactivity and organic synthesis
- Know difference of photoinduced electron transfer and energy transfer to induce organic reactions
- Know the special significance of visible light excitation

Content
1. Photophysical basics
2. Organic photochemistry
   2.1 Principles
   2.2 Photoadditions
   2.3 Photolyses
   2.4 Photoisomerization and molecular switches
3. Photocatalysis
   3.1 Flavin photocatalysis
   3.2 Template photocatalysis
   3.3 Introduction in photoredoxcatalysis
   3.4 Photoredoxorganocatalysis
   3.5 Water splitting
4. Bioorganic photochemistry
   4.1 Photocleavable groups
   4.2 Photoaffinity labeling
   4.3 Singulet oxygen, photodynamic therapy and chemiluminescence
4.4 Photoinduced electron transfer in DNA

**Recommendations**
Solid background in organic chemistry.

**Literature**

**Workload**
total 90 h, hereof 30 h contact hours (lecture) and 60 h recapitulation and self-studies
Module: Imaging Techniques in Light Microscopy (Sp-ITL) [M-CHEMBIO-101905]

Responsibility: Martin Bastmeyer

Organisation: KIT-Fakultät für Chemie und Biowissenschaften

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Biomedical Photonics / Elective Modules

Additional Achievements

ECTS

Recurrence

Duration

Language

Version

3

Each winter term

1 term

English

2

Compulsory

Identifier

Course

ETCS

Responsibility

T-CHEMBIO-105197

Imaging Techniques in Light Microscopy

3

Martin Bastmeyer

Learning Control / Examinations

Type of Examination: Oral or written exam

Duration of Examination: 45 min (oral) or 120 min (written)

Modality of Exam: Depending on the number of participants, an oral or written exam is accomplished. The exact modality of the exam will be announced at the beginning of the semester. The written exam is scheduled for the beginning of the break after the WS. A resit exam is offered at the end of the break.

Conditions

Attendance to the lecture.

Qualification Objectives

The students

- are able to derive the description of geometric- and wave-optical principles of a compound microscope
- know the physical principles of fluorescent dyes
- understand the configuration of laser scanning microscopes
- comprehend digital imaging and image processing
- have experienced a hands on laboratory praxis of the different microscopic techniques
- understand the biological principles of GFP-expression
- know the latest developments in light microscopy
- understand how technical development of microscopes has driven basic biological research

Content

This lecture series is designed to gain familiarity with fundamentals of biological light microscopy and modern fluorescence techniques. Depending on the content, the students will have lab demonstrations of different microscopes or imaging techniques covered in the lecture.

I. Introduction (History and Basic Principles of Compound Microscopes, Resolution and Contrast, Biological Sample Preparation)

II. Imaging Modes and Contrast Techniques (Biological Amplitude and Phase Objects, Phase Contrast, Interference Contrast, Polarization Microscopy)

III. Fluorescence Microscopy (Microscopic Principles, Fluorescent Dyes and Proteins, Biological Sample Preparation)

IV. Laser-Scanning-Microscopy (Basic Principles, Spinning Disk, 2-Photon Microscopy, Optical Sectioning Techniques)

V. Live Cell Imaging (Video Microscopy, Fluorescent Proteins)

VI. Special Fluorescence Techniques (FRET, TIRF, FCS)

VII. Super Resolution Microscopy (SIM, PALM, dSTORM, STED)

VII. Digital images (Image Processing, Data Analysis and Quantification)

Recommendations

Basic knowledge in physics and biology
Literature
Lecture presentations will be accessible in pdf-format
Recent review articles will be distributed before the lectures
Books:
Alan R. Hibbs: Confocal Microscopy for Biologists, Springer Press
Rafael Yuste (Ed.): Imaging, a laboratory manual, CSH Press
James Pawley: Handbook of biological confocal microscopy, Plenum Press

Workload
Total 90 h, hereof 30 h contact hours (30 h lecture), and 60 h homework and self-studies
Module: Optics and Vision in Biology (Sp-OVB) [M-CHEMBIO-101906]

Responsibility: Martin Bastmeyer
Organisation: KIT-Fakultät für Chemie und Biowissenschaften
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Biomedical Photonics / Elective Modules

Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-CHEMBIO-105198 Optics and Vision in Biology 4 Martin Bastmeyer

Learning Control / Examinations
Type of Examination: Written exam
Duration of Examination: 120 Minutes
Modality of Exam: The written exam is scheduled for the break after the WS. A resit exam will be offered, when needed.
Conditions
Attendance to the lecture.

Qualification Objectives
The students
- understand the anatomy and optics of the vertebrate eye and its aberrations
- comprehend retinal microanatomy and its relation to retinal computation
- are familiar with the wiring of the retinofugal pathways in vertebrates
- know their roles in circadian rhythm, pupillary reflex and gaze control
- conceive the details of higher visual processing in the thalamocortical pathway
- know how cortical processing achieves visual scene segmentation and feature binding
- understand the psychophysics of the perception of brightness, color, shape, depth and motion
- are acquainted with the different types of eyes in lower animals
- can distinguish microvillated and ciliated photoreceptors
- are able to analyze the function of compound eyes and the insect visual system
- can conceptualize the molecular details of phototransduction in the different types of photoreceptors
- understand the quantum bump as the signature of single-photon sensitivity
- comprehend microbial light sensing and its influence on circadian clocks, phototropism, reproduction
- know the underlying phytochromes and associated proteins
- understand how light can regulate gene expression in microorganisms
- have grasped the mechanisms of green plant photosynthesis
- conceive the structure and function of chloroplasts, antenna complexes and photosystems
- have conceptualized the underlying energy transfer cascades, electron transport chain as well as the Calvin cycle of carbon fixation
- comprehend the light path in leaves
- know the Kautsky effect involving fluorescence and photosynthesis
- understand the advantages and disadvantages of biofuels
- are familiar with the principles of optogenetics as a means to genetically engineer organisms to induce light sensitivity.

Content
Evolution has developed abundant ways of harnessing light for the benefits of life. Through plant photosynthesis, life manifestations of all higher species are powered by solar energy. Light sensing has evolved a bewildering variety of forms
ranging from light control of reproduction, germination, development in microorganisms to sophisticated visual processing in higher animals. In this course, students will develop a conceptual understanding of the overwhelming importance of light in these natural biological processes. Learning from nature might enable them in the future to generate novel ideas for technological applications of light, ranging from sustainable energy conversion to computer vision.

I. The vertebrate eye and retina
II. Central visual pathways in vertebrates
III. Visual processing and perception in the human cortex
IV. Invertebrate eyes – evolution, architecture and function
V. Phototransduction
VI. Microbial phytochromes and light sensing
VII. Photosynthesis
VIII. Optogenetics

Recommendations
Passed exam of the Adjustment Course in “Basic Molecular Cell Biology” AdjC-BMCB.

Literature
lecture presentations are provided in pdf-format
Neuroscience, Purves, D. et al., Sinauer, 2011

Workload
Total 120 h, hereof 40 h contact hours and 80 h homework and self-studies
Module: Advanced Lithography for Biophotonic & Optofluidic Applications

[M-MACH-103126]

Responsibility: Timo Mappes
Organisation: Institut für Mikrostrukturtechnik
Curricular Anchorage: Compulsory Elective
Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Optical Systems

Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-MACH-106206 Advanced Lithography for Biophotonic & Optofluidic Applications 3 Timo Mappes

Learning Control / Examinations

Type of Examination: oral exam
Duration of Examination: 20 Minutes
Modality of Exam: The oral exam is by appointment.

Conditions
None

Qualification Objectives

While fulfilling the learning targets, the students are familiar with the working principle of scanning electron microscopes and their similarity to electron beam lithography, including electron sources and machine types. They understand secondary effects and can develop solutions how to avoid those for lithography. They understand the working principle of focussed ion beam machines and their application in fabrication, preparation and (correlative) microscopy.

are familiar with the processes required for multi-photon-lithography in resist and glass as well as their application for (hybrid) optofluidic and biophotonic systems.

understand the physical effects in advanced immersion and next generation lithography, in particular EUV lithography know how to evaluate a new lithographical method and may elaborate on its probability to be introduced in mass fabrication. In particular, they have a good understanding of the challenges in microfabrication, including the strategies to avoid pattern defects like e.g. structure collapse

understand the applicative needs and technical production prerequisites for the generation of scaffolds to be used as tools for the study of cell clusters e.g. in biology and medicine

are familiar with the realization of optofluidic systems to be used for integrated sensing, light guiding and tailored particle fabrication

Content

This module is introducing the application of advanced lithographic patterning for applications in optofluidics and biophotonics. With an overview on typical applications of micro optical and nano photonic systems, the challenges of lithographic patterning for their fabrication are motivated. The fabrication chain for high-end structures covering is discussed, starting from electron beam machines and their similarities to scanning electron microscopes. The available and the perspective for new and novel processes of parallel and serial lithography are discussed. The working principles of lithography machines as well as their limitations are presented. Aspects for masked-based optical lithography and multi-photon lithography in a broad range of materials are elaborated on. The challenges for resolution enhancement with immersion lithography are discussed by a problem-based learning approach. Subsequently the numerous technological
(including source and beam-shaping) and economic implications of the introduction of extreme ultra violet (EUV) lithography are discussed. In order to consolidate the interrelations of the individual process steps, the micro fabrication of (hybrid) optofluidic and biophotonic systems are discussed in detail. The particular boundary conditions to enable the application of those systems in biology and medicine as well as in sensing and imaging are elaborated on.

**Recommendations**
Basic knowledge in physics.

**Literature**

References to journal publications during the lecture

**Workload**
total 90 h, hereof 30 contact hours (30 h lecture), and 60 h homework and self-studies
Module: Optical Systems in Medicine and Life Science  [M-ETIT-103252]

Responsibility: Werner Nahm

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Biomedical Photonics / Elective Modules
Specialization / Specialization - Optical Systems

Additional Achievements

ECTS 3
Recurrence Each winter term
Duration 1 term
Language English
Version 2

Compulsory

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Learning Control / Examinations
Type of Examination: Results of 4 case studies (protocols & presentations)
Modality of Exam: The examination is the presentation of the 4 case works by the team plus the written protocol of the case work including the required documentation.

Module Grade
The grade is calculated from the presentations and protocols of 3 case studies and one hands-on experience.

Conditions
None

Qualification Objectives
Students have formulated use cases and requirements for complex medical devices from different perspectives: user, system engineer, development engineer
Students have systematically broken down complex systems to functional components. The underlying physics and physiology have been described in detail.
Students have explained and operated the systems and evaluated the results.
Students have identified new technical solutions based on current problem descriptions. They have prepared development plans for implementing product improvements into the product life cycle.
Students have contributed to their team with their creativity, technical know-how, and personal working style. They have presented and defended team results as well as own contributions.

Content
Part 1:
Case study: Basics
- Fields of application for optical systems in medicine and life sciences
- Physical and physiological basics
- Basics for complex systems development
Part 2:
Case study: Systems and components
- System design and system architecture
- Component design and functionality
Part 3:
Hands-on experience
Part 4:
Case study: System Enhancements
Recommendations
None

Remarks
Language English

Literature
M. Kaschke, Optical Devices in Ophthalmology and Optometry, Willey-VCH

Workload
total 90 h, hereof 30 h contact hours and 60 h homework and self-studies
Module: Adaptive Optics  [M-ETIT-103802]

Responsibility: Ulrich Lemmer
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Biomedical Photonics / Elective Modules
Specialization / Specialization - Optical Systems

ECTS 3
Recurrence Each winter term
Duration 1 term
Language English
Version 2

Compulsory

Identifier Course ECTS Responsibility
T-ETIT-107644 Adaptive Optics 3 Ulrich Lemmer

Learning Control / Examinations
Type of Examination: Oral examination
Duration of Examination: 30 Minutes
Modality of Exam: The oral exam is scheduled two weeks after WS.

Qualification Objectives
Course Description
Adaptive optics is a technology of correcting the effect of atmospheric turbulence on images of space objects and on laser beams propagating through random and highly aberrated media such as turbulence, tissue, and the inside of the human eye, to name just a few applications. The course will familiarize the students with theoretical basics of light propagation through random media, principles of wavefront sensing and reconstruction, as well as wavefront correction with deformable mirrors.

The students will also receive solid introduction to statistical optics, the Kolmogorov theory of turbulence, practical aspects of turbulence simulation and modelling of adaptive optics performance. Design of adaptive optics systems through error budget equations, simulations and analytical models will be discussed. Applications from astronomy, free-space laser communications and medicine will be given.

Learning targets
The students will:
- get familiar with Fourier description of imaging through aberrated optical systems and random media,
- understand the description of aberrations through Zernike modes,
- learn how to analytically compute the effects of turbulence on various optical observables such as image/beam motion, temporal power spectra, Zernike modes, scintillation, etc.,
- understand the effect of noise on various quantities and metrics pertinent to the design of adaptive optical systems,
- understand the advantages and disadvantages of various schemes for wavefront sensing and correction,
- learn how to simulate and design simple adaptive optics systems.

Content
1. Theory of turbulence
2. Fourier optics
3. Statistical optics
4. Sources and description of aberrations
5. Adaptive optics systems
6. Wavefront sensing
7. Wavefront correction
8. Simulation of adaptive optical systems

**Recommendations**
Fourier analysis, statistics, classical optics, probability theory

**Literature**

**Workload**
total 90 h, hereof 30 h contact hours and 60 h homework and self-studies
11.4 Specialization - Optical Systems

Module: Laser Metrology [M-ETIT-100434]

Responsibility: Christian Koos
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Optical Systems
Additional Achievements

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**Compulsory**

Identifier | Course | ECTS | Responsibility
---|--------|------|------------------
T-ETIT-100643 | Laser Metrology | 3 | Christian Koos

**Learning Control / Examinations**

Type of Examination: Oral examination
Duration of Examination: 30 minutes
Modality of Exam: The oral exam is scheduled for the beginning of the break after the SS

**Conditions**

No formal prerequisites. However, steady participation in the lecture as well as thorough preparation based on the scriptum is highly recommended.

**Qualification Objectives**

The students:
- know the fundamental properties of laser light
- comprehend the different information accessible by laser metrology
- understand the fundamentals of different detectors and their limits for beam diagnostics
- comprehend several laser-metrological setups: Moiré, range and velocity measurements, absorption and scattering techniques.

**Content**

1. Laser diagnostics - theoretical considerations (laser beam properties, coherence, spectral emission of lasers, mode structure and selection, coherence length)
2. Metrological accessible information (propagation in homogeneous and isotropic, in inhomogeneous and in anisotropic media)
3. Beam diagnostics (photoelectric detectors, information theory, granulation properties of laser light)
4. Laser-Interferometer (fundamentals, two-beam Interferometer, interferometry applications in plasma physics, two- and multiwavelength-interferometry, laser gyroscopes)
5. Moiré technique (Moiré deflectometry, Fresnel- and Fraunhofer diffraction, applications and evaluation of the Moiré technique)
6. Laser range measurements (fundamentals, atmospheric influence on propagation, optical distance measurement techniques, accuracy, sensitivity, heterodyne detection, selected heterodyne detection schemes, tomoscopy)
7. Laser velocity measurement techniques (Doppler principle, measuring flow velocities using Doppler effect, the two-focus technique or laser anemometry; time-resolved imaging particle-trace anemometry)
8. Absorption and scattering techniques (absorption techniques, LIDARs, scattering processes in laser diagnostics, spontaneous scattering techniques, spectroscopic techniques, stimulated scattering, nonlinear optical laser light scattering techniques)
**Recommendations**
Solid mathematical background, basic knowledge in physics

**Literature**
M. Eichhorn, *Laser metrology* - Scriptum

**Workload**
total 90 h, hereof 30 h contact hours (30 h lectures) and 60 h recapitulation and self-studies
Module: Laser Physics  [M-ETIT-100435]

Responsibility: Christian Koos

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Optical Systems

Additional Achievements

ECTS Recurrence Duration Language Version
4 Each winter term 1 term English 1

Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100741 Laser Physics 4 Christian Koos

Learning Control / Examinations
Type of Examination: Oral examination
Duration of Examination: 30 minutes
Modality of Exam: The oral exam is scheduled for the beginning of the break after the WS.

Conditions
No formal prerequisites. However, steady participation in lecture and tutorial as well as thorough preparation based on the scriptum is highly recommended.

Qualification Objectives
The students

- know the fundamental relations and background of lasers
- gain the necessary knowledge for understanding and dimensioning of lasers, laser media, optical resonators and pump strategies
- understand the pulse generation with lasers and their fundamental relations
- obtain the necessary knowledge on several lasers: gas-, solid state, fiber- and disc-lasers in the visible and middle infrared range

Content
1 Quantum-mechanical fundamentals of lasers
1.1 Einstein relations and Planck’s law
1.2 Transition probabilities and matrix elements
1.3 Mode structure of space and the origin of spontaneous emission
1.4 Cross sections and broadening of spectral lines
2 The laser principles
2.1 Population in version and feedback
2.2 Spectroscopic laser rate equations
2.3 Potential model of the laser
3 Optical Resonators
3.1 Linear resonators and stability criterion
3.2 Mode structure and intensity distribution
3.3 Line width of the laser emission
4 Generation of short and ultra-short pulses
4.1 Basics of Q-switching
4.2 Basics of mode locking and ultra-short pulses
5 Laser examples and their applications
5.1 Gas lasers: The Helium-Neon-Laser
5.2 Solid-state lasers
5.2.1 The Nd³⁺-Laser
5.2.2 The Tm³⁺-Laser
5.2.3 The Ti³⁺:Al₂O₃ Laser
5.3 Special realisations of lasers
5.3.1 Thermal lensing and thermal stress
5.3.2 The fiber laser
5.3.3 The thin-dis laser

Recommendations
Solid mathematical background, basic knowledge in physics

Literature
M. Eichhorn, Laser physics (Springer)
M. Eichhorn, Laserphysik (Springer)
A. E. Siegman, Lasers (University Science Books)
B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics (Wiley-Interscience)
F. K. Kneubühl, M. W. Sigrist, Laser (Teubner)

Workload
total 120 h, hereof 45 h contact hours (30 h lectures, 15 h tutorial) and 75 h recapitulation and self-studies
Module: Optical Transmitters and Receivers [M-ETIT-100436]

Responsibility: Wolfgang Freude

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
  Specialization / Specialization - Optical Systems
  Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100639 Optical Transmitters and Receivers 4 Wolfgang Freude

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 Minutes
Modality of Exam: Oral examination, usually one examination day per month during the Summer and Winter terms. An extra questions-and-answers session will be held if students wish so.

Conditions
Exercise sheet can be downloaded as homework each week. Active participation in the problem classes is advised. Studying in learning groups is strongly recommended.

Qualification Objectives
The students understand the peculiarities of optical communications, and how optical signals are generated, transmitted and received,
know about sampling, quantization and coding,
learn the basics about noise on reception,
understand the properties of a linear and a nonlinear optical fibre channel,
grasp the idea of channel capacity and spectral efficiency,
know about various forms of modulation,
acquire knowledge of optical transmitter elements,
understand the function of optical amplifiers,
have a basic understanding of optical receivers,
know the sensitivity limits of optical systems, and understand how these limits are measured.

Content
The course concentrates on basic optical communication concepts and connects them with the properties of physical components. The following topics are discussed:

- Advantages and limitations of optical communication systems
- Optical transmitters comprising lasers and modulators
- Optical receivers comprising direct and heterodyne reception
- Characterization of signal quality

Recommendations
Minimal background required: Calculus, differential equations, Fourier transforms and p-n junction physics
Literature
Detailed textbook-style lecture notes can be downloaded from the IPQ lecture pages.
Electronic version available via w.freude@kit.edu.

Workload
total 120 h, hereof 33 h contact hours, (15 x 1.5 h = 22h lecture, 15 x 0.75 h = 11 h problem class), and 97 h homework and self-studies
Module: Optical Waveguides and Fibers  [M-ETIT-100506]

Responsibility: Christian Koos

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems

Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-101945 Optical Waveguides and Fibers 4 Christian Koos

Learning Control / Examinations

Type of Examination: Oral
Duration of Examination: 20 Minutes
Modality of Exam: The written exam is offered continuously upon individual appointment.

Conditions

There are no prerequisites for participating in the examination.
There is, however, a bonus system based on the problem sets that are solved during the tutorials: During the term, 3 problem sets will be collected in the tutorial and graded without prior announcement. If for each of these sets more than 70% of the problems have been solved correctly, a bonus of 0.3 grades will be granted on the final mark of the oral exam.

Qualification Objectives

The students

- conceive the basic principles of light-matter-interaction and wave propagation in dielectric media and can explain the origin and the implications of the Lorentz model and of Kramers-Kronig relation,
- are able to quantitatively analyze the dispersive properties of optical media using Sellmeier relations and scientific databases,
- can explain and mathematically describe the working principle of an optical slab waveguide and the formation of guided modes,
- are able to program a mode solver for a slab waveguide in Matlab,
- are familiar with the basic principle of surface plasmon polariton propagation,
- know basic structures of planar integrated waveguides and are able to model special cases with semi-analytical approximations such as the Marcatili method or the effective-index method,
- are familiar with the basic concepts of numerical mode solvers and the associated limitations,
- are familiar with state-of-the-art waveguide technologies in integrated optics and the associated fabrication methods,
- know basic concepts of of step-index fibers, graded-index fibers and microstructured fibers,
- are able to derive and solve basic relations for step-index fibers from Maxwell’s equations,
- are familiar with the concept of hybrid and linearly polarized fiber modes,
- can mathematically describe signal propagation in single-mode fibers design dispersion-compensated transmission links,
- conceive the physical origin of fiber attenuation effects,
- are familiar with state-of-the-art fiber technologies and the associated fabrication methods,
- can derive models for dielectric waveguide structures using the mode expansion method,
- conceive the principles of directional couplers, multi-mode interference couplers, and waveguide gratings,
- can mathematically describe active waveguides and waveguide bends.
Content

1. Introduction: Optical communications
2. Fundamentals of wave propagation in optics: Maxwell’s equations in optical media, wave equation and plane waves, material dispersion, Kramers-Kroig relation and Sellmeier equations, Lorentz and Drude model of refractive index, signal propagation in dispersive media.
3. Slab waveguides: Reflection from a plane dielectric boundary, slab waveguide eigenmodes, radiation modes, inter- and intramodal dispersion, metal-dielectric structures and surface plasmon polariton propagation.
4. Planar integrated waveguides: Basic structures of integrated optical waveguides, guided modes of rectangular waveguides (Marcatili method and effective-index method), basics of numerical methods for mode calculations (finite difference- and finite-element methods), waveguide technologies in integrated optics and associated fabrication methods
5. Optical fibers: Optical fiber basics, step-index fibers (hybrid modes and LP-modes), graded-index fibers (infinitely extended parabolic profile), microstructured fibers and photonic-crystal fibers, fiber technologies and fabrication methods, signal propagation in single-mode fibers, fiber attenuation, dispersion and dispersion compensation
6. Waveguide-based devices: Modeling of dielectric waveguide structures using mode expansion and orthogonality relations, multimode interference couplers and directional couplers, waveguide gratings, material gain and absorption in optical waveguides, bent waveguides

Recommendations
Solid mathematical and physical background, basic knowledge of electrodynamics

Literature
B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics
G.P. Agrawal: Fiber-optic communication systems
C.-L. Chen: Foundations for guided-wave optics
Katsunari Okamoto: Fundamentals of Optical Waveguides
K. Iizuka: Elements of Photonics

Workload
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial) and 75 h homework and self-studies.
Module: Light and Display Engineering  [M-ETIT-100512]

Responsibility: Rainer Kling

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Optical Systems

Additional Achievements

ECTS 4
Recurrence Each winter term
Duration 1 term
Language English
Version 1

Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100644 Light and Display Engineering 4 Rainer Kling

Learning Control / Examinations

Type of Examination: Oral exam
Duration of Examination: 25 Minutes
Modality of Exam: The oral exam is flexibly held by student request after the WS.

Conditions
None

Qualification Objectives

The students will apply their comprehensive knowledge of physics of optical phenomena to applied optical systems in light and display engineering. These applications span from human sensing with the eye to light technologies with lamps, luminaires and displays. The course gives a broad overview how optics can be applied in modern technology fields. The subjects taught are further clarified by demonstrations, models and experiments.

The students
• can derive the description of basic of light engineering starting from the eye and the visual system
• know how to handle basic metrical units and know how to measure them
• understand the visible sensing in contrast to radiation measurements
• comprehend the concepts of colour and colour control
• are familiar with all types of light sources from low pressure lamps to LED modules
• conceive the operation principle of various types of drivers
• know how to set up a luminaire and how simulate a reflector
• they understand how active (Plasma Displays) and passive displays (TFT Display) work and how to operate them
• have a good visualization of numerous optical design approaches

Content

1. Motivation: Light & Display Engineering
2. Light, the Eye and the Visual System (including Melatonin)
3. Fundamentals in Light Engineering
4. Light in non-visual Processes (UV Processes)
5. Color and Brightness
6. Light Sources (Halogen, Low Pressure and High Pressure Lamps, LED Engines) and electronic Drivers
7. Displays (Active and Passive Displays: AMOLED, E-ink, TFT Display, Plasma Display)
8. Luminaries (Fundamentals, Design Rules, Simulations)
9. Optical Design (Ray tracing, Reflector design, Computed Ray tracing)

Recommendations

Basic physics background
**Literature**

Shunsuke Kobayashi: LCD Backlights, 2009  
Malacara, Handbook of Optical Design, 2004

**Workload**

total 120 h, hereof 45 h contact hours (lecture and tutorial), and 75 h homework and self-studies
Module: Systems and Software Engineering [M-ETIT-100537]

Responsibility: Eric Sax
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Optical Systems

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Compulsory

Identifier | Course | ECTS | Responsibility
---|---|---|---
T-ETIT-100675 | Systems and Software Engineering | 4 | Eric Sax

Learning Control / Examinations
Written (see actual document “Studienplan” and notice of the examination office ETIT).

Module Grade
Grades result from the written examination.

Conditions
none

Qualification Objectives
The students:
§ know the most important Life Cycle and process models (including V-Model and agile methods).
§ are capable of choosing a suitable method to design and evaluate complex systems.
§ know the most important diagram types of hardware and software modeling languages and can design such diagrams from characterization of an application area.
§ know the basic methods for quality assurance, which are needed during project development. They know the different test phases of a project and can evaluate the reliability of a system.
§ They are familiar with the issues of functional safety and the standards of process evaluation.

Content
Major topics are techniques and methods for the design of complex electric, electronic and electronic programmable systems with software fragments and hardware fragments. The competences of the course comprise comprehensive knowledge and goal-oriented usage of state of the art modeling techniques, development processes, description techniques as well as specification languages.

Recommendations
Participation in the lectures Digital System Design (23615) and Information Technology (23622) is advised

Workload
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial) and 75 h homework and self-studies
Module: Field Propagation and Coherence  [M-ETIT-100566]

Responsibility: Wolfgang Freude
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100976 Field Propagation and Coherence 4 Wolfgang Freude

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 Minutes
Modality of Exam: Oral examination, usually one examination day per month during the summer and winter terms. An extra questions-and-answers session will be held for preparation if students wish so.

Conditions
There are no prerequisites, but solution of the problems on the exercise sheet, which can be downloaded as homework each week, is highly recommended. Also, active participation in the problem classes and studying in learning groups are strongly advised.

Qualification Objectives
Presenting in a unified approach the common background of various problems and questions arising in general optics and optical communications
The students

- know the common properties of counting of modes, density of states and the sampling theorem
- comprehend the relationship between propagation in multimode waveguides, mode coupling, MMI and speckles
- can analyze propagation in homogeneous media with respect to system theory, antennas, and the resolution limit of optical instruments
- understand that coherence as a general concept comprises coherence in time, in space and in polarisation
- comprehend the implication of complete spatial incoherence, and what is the radiation efficiency of a source with a diameter smaller than a wavelength (the mathematical Hertzian dipole, for instance)
- can assess when can two incandescent bulbs form an interference pattern in time
- know under which conditions a heterodyne radio receiver, which is based on a non-stationary interference, actually works

Content
The following selection of topics will be presented:

- Light waves, modes and rays: Longitudinal and transverse modes, sampling theorem, counting and density of modes ("states")
- Propagation in homogeneous media: Resolution limit. Non-paracial and paracial optics. Gaussian beam. ABCD matrix

**Recommendations**
Minimal background required: Calculus, differential equations and Fourier transform theory. Electrodynamics and field calculations or a similar course on electrodynamics or optics is recommended.

**Literature**
Detailed lecture notes as well as the presentation slides can be downloaded from the IPQ lecture pages. Additional reading:
Hecht, E.: Optics, 2. Ed. Reading: Addison-Wesley 1974
Further textbooks in German (also in electronic form) can be named on request

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies
Module: Lighting Design - Theory and Applications  [M-ETIT-100577]

Responsibility: Rainer Kling
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Optical Systems

Additional Achievements

ECTS
Recurrence Duration Language Version
3 Each winter term 1 term English 1

Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100997 Lighting Design - Theory and Applications 3 Rainer Kling

Learning Control / Examinations
Type of Examination: Oral exam
Duration of Examination: 25 Minutes
Modality of Exam: The oral exam is flexibly held by student request after the WS.

Conditions
None

Qualification Objectives
The students will apply a comprehensive knowledge of Lighting Design from theory, standards and applications in Indoor and Outdoor lighting. Examples and own Lighting design examples as projects. So a practical and theoretical background is applied to Lighting Design. From metrics too Light Planning projects in small exercise groups. The subjects taught are further clarified by demonstrations, models and experiments. Attending students get the knowledge to Lighting Design, in a shorter theoretical part and practical lighting design simulations with examples from all over the world.

The students

- can derive the description of basics of Lighting Design
- know how to handle basic metrical units and know how to measure them
- understand the Lighting Design metrics to apply on projects
- have a good visualization of numerous design approaches
- realize good Lighting Design with codes and standards.
- can see energy savings levels for Lighting Design
- comprehend the lighting design by practical self-computing lessons:
- can realize own indoor Lighting design concepts for different applications like Office, School, Shops, Gyms & Industry
- can realize own outdoor Lighting Design concepts for Street lighting, Tunnels, Stade and Parkings
- can use for realization Relux and Dialux light planning software so set up Project Planning for Lighting Design.

Content
1. Lighting Design - Introduction form all over the world
2. Lighting Fundamentals
3. Lighting Design Theory
4. Energy Savings and Lighting design
5. Lighting Design Tools
6. Computing Standards
7. Lighting Design Applications (Practical Part)
   7.1 Interior Lighting
   7.2 Exterior lighting
   7.3 Illumination
Own Calculation Examples (Practical Part)

Motivation: Light & Display Engineering
8. Own Calculation Examples (Practical Part)

**Motivation:** Light & Display Engineering

**Recommendations**
Basic physics background

**Literature**
- M. Karlen: *Lighting Design Basics, Indoor Lighting*, 2004

**Workload**
total 90 h, hereof 45 h contact hours (Seminar), and 45 h homework and self-studies
Module: Laser Materials Processing (Sp-LMP) [M-ETIT-101914]

**Responsibility:** Thomas Graf

**Organisation:** KIT-Fakultät für Elektrotechnik und Informationstechnik

**Curricular Anchorage:** Compulsory Elective

**Contained in:** Specialization / Specialization - Optical Systems

**Curricular Anchorage:** Compulsory Elective

**Learning Control / Examinations**

- **Type of Examination:** oral exam
- **Duration of Examination:** 20 Minutes
- **Modality of Exam:** Oral exams on arrangement

**Conditions**

None

**Qualification Objectives**

The goal of the module is to gain knowledge and understanding of the manifold applications of the laser, especially for welding, cutting, drilling, structuring, and surface treatment. The students know and understand the numerous application possibilities of the laser in welding, cutting, drilling, structuring, and surface treatment. They understand which properties of the laser beam, material, and environment influence the processes in which way are able to judge and to improve the quality and efficiency of laser based processes.

**Content**

I. Introduction
II. The Tool (Laser Beams, Generation of Laser Beams, Laser Beam Sources, System Engineering)
IV. The Processes (Cutting, Welding, Surface Treatments, Drilling and Structuring)

**Recommendations**

Basic knowledge of physics and mathematics for the solution of simple equations

**Literature**

Hügel, Graf: Laser in der Fertigung – Grundlagen der Strahlquellen, Systeme, Fertigungsverfahren, Vieweg+Teubner
ISBN: 978-3-8348-1817-1

**Workload**

total 90 h, hereof 21h contact hours, and 79h homework and self-studies
Module: Research Project  [M-PHYS-102194]

Responsibility: Heinz Kalt
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Biomedical Photonics / Elective Modules
Specialization / Specialization - Optical Systems
Specialization / Specialization - Solar Energy / Elective Modules
Additional Achievements

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Learning Control / Examinations
The date of the project work is to be fixed individually. The format can be:

- a 1.5 week block course in the semester break
- a consecutive work of 4h/week during the entire semester

A written report of about 10 pages (at the discretion of the supervisor) concludes the Research Project. The overall performance of the students will be graded. The mark and the allocated 4CP are optional part of the elective courses in the specialization direction.

Conditions
None.

Qualification Objectives
The Research Project augments the theoretical knowledge acquired in the elective lecture courses by application to hands-on research in the respective KSOP research area. Hereby the student will also explore possible topics for the subsequent master thesis.

The students
- get in-depth insight into a special research topic
- get hands-on experience in experimental and/or theoretical techniques
- learn how to obtain and evaluate relevant scientific literature
- get first experience on how to plan and organize a research project
- learn how to write a scientific report has the possibility to explore a topic for her/his Master’s Thesis

Content
The 3rd semester Research Project is optional, but highly recommended for students not working in a KSOP institute as research assistants. Accordingly, the topics of the Research Projects are provided by the KSOP PIs on an individual basis. The projects are supposed to complement the set of elective lecture courses within the specialization area of the student. The topics of the Research Projects are constantly adapted to the current research within KSOP.

Recommendations
Basic background in optics and photonics.

Literature
Literature is provided by the supervisors of the individual projects.
Workload

total 120 h, hereof 60 h contact hours (supervised research) and 60 h preparation of report and self-studies
Module: Machine Vision (Sp-MV) [M-MACH-101923]

Responsibility: Martin Lauer, Christoph Stiller
Organisation: KIT-Fakultät für Maschinenbau
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Optical Systems

Additional Achievements
ECTS 6
Recurrence Each winter term
Duration 1 term
Language English
Version 1

Compulsory

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<td>T-MACH-105223</td>
<td>Machine Vision</td>
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<td>Martin Lauer, Christoph Stiller</td>
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Learning Control / Examinations
Type of Examination: written exam
Duration of Examination: 60 Minutes
Modality of Exam: Written exam
Conditions
None.

Qualification Objectives
Machine vision (or computer vision) describes the computer supported solution of visual tasks similar to human vision. The technical domain of machine vision includes numerical research areas like optics, digital signal processing, 3d measurement technology, and pattern recognition. Application areas for machine vision techniques can be found in automation and control, robotics, and intelligent vehicles, among others.

The lecture introduces the basic machine learning techniques and algorithms and illustrates their use. The lecture is composed out of 3 hours/week lecture and 1 hour/week computer exercises. In the computer exercises methods introduced in the lecture will be implemented in MATLAB and tested experimentally.

Content
1. Overview of machine vision
2. Image formation and image preprocessing techniques
3. Edge detection
4. Line and curve fitting
5. Color representation
6. Image segmentation
7. Camera optics and camera calibration
8. Illumination
9. 3d reconstruction
10. Pattern recognition

Recommendations
Solid mathematical background.

Workload
total 180 h, hereof 60 h contact hours (45 h lecture, 15 h computer exercises), and 120 h homework and self-studies
Module: Plastic Electronics / Polymerelectronics [M-ETIT-100475]

Responsibility: Ulrich Lemmer

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Optical Systems
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

ECTS
- Recurrence: Each winter term
- Duration: 1 term
- Language: German/English
- Version: 1

Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100763 Plastic Electronics / Polymerelectronics 3 Ulrich Lemmer

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 20 min
Modality of Exam: Oral exam (20 minutes)

Conditions
None.

Qualification Objectives
To enquire during lecture.

Content
1. Introduction
2. Electronic Structure of organic (macro) molecules
3. Optical properties of organic semiconductors
4. electronic transport
5. Light emitting diodes
6. organic solid state lasers
7. Xerography
8. Photovoltaic cells
9. Organic field effect transistors
10. Organic electroluminescent displays
11. Device fabrication

Recommendations
None.

Literature
The corresponding documents are available online in the VAB (https://studium.kit.edu/)

Workload
total 90 h, hereof 30 h lecture, and 60 h recapitulation and self-studies
Module: Quantum Optics \[M\text{-PHYS-103093}]\n
Responsibility: Carsten Rockstuhl
Organisation: KIT-Fakultät für Physik
Curricular An-<br>chorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Optical Systems
Additional Achievements

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Learning Control / Examinations
Type of Examination: Written or oral examination
Duration of Examination: 90 minutes (written), 30 minutes (oral)
Modality of Exam: There will be a written or an oral examination, depending on the number of participants. This will be settled after the end of the fourth lecture. The written examination lasts for 90 minutes and shall be written without any supporting documents. The oral examination will last for 30 minutes.

Conditions
A minimum amount of correct solutions of the exercises that are biweekly distributed. Details will be announced in the lecture.

Qualification Objectives
The students shall learn to appreciate that quantum optics has been a framework to understand properties of light, which can by no means described with a classical theory, shall learn how to apply various methods from quantum mechanics to specific situation of quantum optics in general and to the description of the light-matter-interaction in specific, shall learn that there are fascinating opportunities to study with micro- and nanooptical systems various quantum optical phenomena, and shall appreciate that even though much of the current research is done out of intellectual curiosity, there are many application perspectives that promise to have a notable impact to our daily life.

Content
- Quantization of the electromagnetic field
- Various quantum states of light fields: optical photon-number, coherent, squeezed, Schrödinger’s cat states
- Classical and quantum coherence theory: photon bunching and antibunching
- Quantum description of optical interferometry: Mach-Zehnder interferometer with photons
- General description of open quantum system: master equation, Heisenberg-Langevin, and stochastic approaches
- Optical test of quantum mechanics: Hong-Ou-Mandel, quantum eraser, and Bell’s theorem experiments
- Interaction of a single atom with a classical field and quantum field
- From Rabi model to Jaynes-Cummings model: the most simplest model to describe the light-matter interaction
- Quantum master equation approach: description of finite life time of atoms
- Weak and strong couplings (spontaneous emission, Purcell effect, resonance fluorescence, lasers, and Rabi oscillation)
- Interaction of an ensemble of atoms with a quantum field (Dicke and Tavis-Cummings models, and superradiance)
- Quantum optical applications (quantum cryptography, quantum teleportation, quantum metrology, etc.)

Recommendations
Solid mathematical background, good knowledge of classical electromagnetism and optics, very good knowledge of quantum mechanics, foremost: interest in doing theoretical work.
11.4 Specialization - Optical Systems

**Literature**
C. Gerry and P. Knight, *Introductory Quantum Optics*.
M. O. Scully and M. S. Zubairy, *Quantum Optics*.
M. Fox, *Quantum Optics: An Introduction*.
R. Loudon, *The Quantum Theory of Light*.
D.F. Walls and G. J. Milburn, *Quantum Optics*.
W. Schleich, *Quantum Optics in Phase Space*.

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial), and 75 h homework and self-studies
Module: Advanced Lithography for Biophotonic & Optofluidic Applications
[M-MACH-103126]

Responsibility: Timo Mappes
Organisation: Institut für Mikrostrukturtechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Biomedical Photonics / Elective Modules
Specialization / Specialization - Optical Systems
Additional Achievements

ECTS: 3
Recurrence: Each winter term
Duration: 1 term
Language: English
Version: 1

Identifier Course ECTS Responsibility
T-MACH-106206 Advanced Lithography for Biophotonic & Optofluidic Applications 3 Timo Mappes

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 20 Minutes
Modality of Exam: The oral exam is by appointment.

Conditions
None

Qualification Objectives
While fulfilling the learning targets, the students
are familiar with the working principle of scanning electron microscopes and their similarity to electron beam lithography, including electron sources and machine types. They understand secondary effects and can develop solutions how to avoid those for lithography. They understand the working principle of focussed ion beam machines and their application in fabrication, preparation and (correlative) microscopy.
are familiar with the processes required for multi-photon-lithography in resist and glass as well as their application for (hybrid) optofluidic and biophotonic systems.
understand the physical effects in advanced immersion and next generation lithography, in particular EUV lithography know how to evaluate a new lithographical method and may elaborate on its probability to be introduced in mass fabrication. In particular, they have a good understanding of the challenges in microfabrication, including the strategies to avoid pattern defects like e.g. structure collapse
understand the applicative needs and technical production prerequisites for the generation of scaffolds to be used as tools for the study of cell clusters e.g. in biology and medicine
are familiar with the realization of optofluidic systems to be used for integrated sensing, light guiding and tailored particle fabrication

Content
This module is introducing the application of advanced lithographic patterning for applications in optofluidics and biophotonics. With an overview on typical applications of micro optical and nano photonic systems, the challenges of lithographic patterning for their fabrication are motivated. The fabrication chain for high-end structures covering is discussed, starting from electron beam machines and their similarities to scanning electron microscopes. The available and the perspective for new and novel processes of parallel and serial lithography are discussed. The working principles of lithography machines as well as their limitations are presented. Aspects for masked-based optical lithography and multi-photon lithography in a broad range of materials are elaborated on. The challenges for resolution enhancement with immersion lithography are discussed by a problem-based learning approach. Subsequently the numerous technological
(including source and beam-shaping) and economic implications of the introduction of extreme ultra violet (EUV) lithography are discussed. In order to consolidate the interrelations of the individual process steps, the micro fabrication of (hybrid) optofluidic and biophotonic systems are discussed in detail. The particular boundary conditions to enable the application of those systems in biology and medicine as well as in sensing and imaging are elaborated on.

**Recommendations**

Basic knowledge in physics.

**Literature**


References to journal publications during the lecture

**Workload**

Total 90 h, hereof 30 contact hours (30 h lecture), and 60 h homework and self-studies
Module: Computational Photonics, without ext. Exercises  [M-PHYS-103089]

Responsibility: Carsten Rockstuhl

Organisation: KIT-Fakultät für Physik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Specialization / Specialization - Solar Energy / Elective Modules
Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-PHYS-106131 Computational Photonics, without ext. Exercises 4 Carsten Rockstuhl

Learning Control / Examinations
Type of Examination: Programming assignment and oral presentation
Duration of Examination: 30 Minutes
Modality of Exam: One month before the end of the lecture period we distribute selected programming task from the field of computational photonics, which we ask you to solve at home. You will be fully prepared in the labwork course to solve those tasks. The examination then consists of an oral presentation at the end of the lecture period. There, you shall discuss the mathematical and physical background, shall outline implementation details and strategies for the problem you was assigned to, and shall present the results of a computation. You should also do a live simulation demonstration to convince your colleagues and us that the program was property implemented.

Conditions
None.

Qualification Objectives
The students shall learn how to use a computer to solve optical problems and how to visualize details of light-matter-interaction to obtain unprecedented insights, shall appreciate different strategies used to solve Maxwell’s equations, shall understand how spatial symmetries and the arrangement of matter in space can be used to formulate Maxwell’s equations such that they are amenable for a numerical solution, shall be able to implement programs by themselves at the end of the course which they can use in their on-going studies, shall learn how to use a computer to discuss and to explore physical phenomena in general and optical in specific, and shall be familiar with basic computational strategies that emerge in photonics, but comparably in any other scientific discipline.

Content
Transfer Matrix Method to describe the optical response from stratified media, Finite Differences to characterize eigenmode in fiber waveguides, Beam propagation method to describe the evolution of light in the realm of integrated optics, Grating methods to predict reflection and transmission from periodically arranged material in 1D and 2D, Mie Theory to describe the scattering of light from individual cylindrical or spherical objects, Finite-Difference Time-Domain method as a general purpose tool to solve micro- and nanooptical problems, Multiple Multipole Method as an approach to describe light scattering from single objects with an arbitrary shape, Greens’ Methods to discuss equally the scattering from single objects but embedded in an inhomogeneous background, Boundary Integral Method to discuss scattering from objects highly efficient using expressions for the fields on the surface.

Recommendations
Solid mathematical background, good knowledge of classical electromagnetism and optics, exposure to basic aspects of computational physics, foremost: interest in doing work numerically.


**Literature**

"Classical Electrodynamics" John David Jackson,  
"Theoretical Optics: An Introduction" Hartmann Römer,  
"Principles of Optics" M. Born and E. Wolf,  
"Computational Electro-magnetics: The Finite-Difference Time Domain Method," A. Taflov and S. C. Hagness,  
"Light Scattering by Small Particles", H. C. van de Hulst.

**Workload**

total 120 h, hereof 45 h contact hours, (30 h lecture, 15 h labwork class), and 75 h homework and self-studies.
Module: Optical Systems in Medicine and Life Science  [M-ETIT-103252]

**Responsibility:** Werner Nahm

**Organisation:** KIT-Fakultät für Elektrotechnik und Informationstechnik

**Curricular Anchorage:** Compulsory Elective

**Contained in:**
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Optical Systems

**Additional Achievements**

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**Learning Control / Examinations**

Type of Examination: Results of 4 case studies (protocols & presentations)

Modality of Exam: The examination is the presentation of the 4 case works by the team plus the written protocol of the case work including the required documentation.

**Module Grade**

The grade is calculated from the presentations and protocols of 3 case studies and one hands-on experience.

**Conditions**

None

**Qualification Objectives**

Students have formulated use cases and requirements for complex medical devices from different perspectives: user, system engineer, development engineer

Students have systematically broken down complex systems to functional components. The underlying physics and physiology have been described in detail.

Students have explained and operated the systems and evaluated the results.

Students have identified new technical solutions based on current problem descriptions. They have prepared development plans for implementing product improvements into the product life cycle.

Students have contributed to their team with their creativity, technical know-how, and personal working style. They have presented and defended team results as well as own contributions.

**Content**

Part 1:

Case study: Basics
- Fields of application for optical systems in medicine and life sciences
- Physical and physiological basics
- Basics for complex systems development

Part 2:

Case study: Systems and components
- System design and system architecture
- Component design and functionality

Part 3:

Hands-on experience

Part 4:

Case study: System Enhancements
Recommendations
None

Remarks
Language English

Literature
M. Kaschke, Optical Devices in Ophthalmology and Optometry, Willey-VCH

Workload
total 90 h, hereof 30 h contact hours and 60 h homework and self-studies
Module: Automotive Vision  [M-MACH-102693]

Responsibility: Martin Lauer, Christoph Stiller

Organisation: KIT-Fakultät für Maschinenbau

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Optical Systems

Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-MACH-105218 Automotive Vision 6 Martin Lauer, Christoph Stiller

Learning Control / Examinations
Type of Examination: Written exam
Duration of Examination: 60 Minutes
Modality of Exam: One written exam offered at the end of each semester.

Conditions
None

Qualification Objectives
Machine perception and interpretation of the environment forms the basis for the generation of intelligent behavior. Especially visual perception opens the door to novel automotive applications. Driver assistance systems already improve safety, comfort and efficiency in vehicles. Yet, several decades of research will be required to achieve an automated behavior with a performance equivalent to a human operator. The lecture addresses students in mechanical engineering and related subjects who intend to get an interdisciplinary knowledge in a state-of-the-art technical domain. Machine vision and advanced information processing techniques are presented to provide a broad overview on seeing vehicles. Application examples from cutting-edge and future driver assistance systems illustrate the discussed subjects. The lecture consists out of 2 hours/week of lecture and 1 hour/week of computer exercises. In the computer exercises methods introduced in the lecture will be implemented in MATLAB and tested experimentally.

Content
1. Basics of machine vision
2. Binocular vision
3. Feature point methods
4. Optical flow
5. Object tracking and motion estimation
6. Self-localization and mapping
7. Road recognition
8. Behavior recognition

Recommendations
None, but knowledge in Machine Vision is useful.

Workload
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h computer exercise) and 75 h homework and self-studies
Module: Optical Networks and Systems  [M-ETIT-103270]

Responsibility: Sebastian Randel

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-106506 Optical Networks and Systems 4 Sebastian Randel

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 20 min
Modality of Exam: Oral exams (20 minutes) are offered throughout the year upon individual appointment.

Conditions
There are no prerequisites for participating in the examination.

Qualification Objectives
The module provides knowledge about optical networks and systems with applications ranging from photonic interconnects, to fiber-to-the-home (FTTH), optical metro and long-haul networks, and automotive and industrial automation. The role of various network layers will be discussed in conjunction with relevant standards and protocols. Physical-layer specifications of relevant photonic components and system design trade-offs will be introduced.

The students
- get familiar with optical network architectures and protocols
- learn how to design optical communication systems in a variety of application scenarios
- understand how application constraints (performance, cost, energy-efficiency) drive technology innovation
- comprehend the benefits and challenges of using optical communication compared to alternatives (e.g. electrical, and wireless)
- are familiar with relevant standardization bodies and are able to interpret essential aspects of standard documents.

Content
Photonic interconnects: rack-to-rack, board-to-board, chip-to-chip, datacenter interconnects, intensity modulation, direct detection, single-mode fiber vs. multi-mode fiber, serial vs. parallel optics, space-division multiplexing vs. wavelength-division multiplexing, Ethernet (10G, 40G, 100G), Fibre Channel, scaling and energy efficiency.

Access networks: fiber-to-the-X, passive optical networks (GPON, EPON, NG-PON2, WDM PON), statistical multiplexing vs. point-to-point

Metro- and long-haul networks:
- System-design aspects: dense WDM (ITU grid), optical amplifiers, chromatic dispersion, coherent detection, optical vs. electronic impairment mitigation, capacity limits.
- Wavelength switching: wavelength selective switch (WSS), reconfigurable optical add-drop multiplexer (ROADM).
- Standards and protocols: synchronous optical networking and synchronous digital hierarchy (SONET/SDH), optical transport network (OTN), generalized multi-protocol label switching (GMPLS), software-defined networking (SDN).

Optical networks in automotive and industrial automation: polymer-optical fiber (POF), MOST Bus, Profibus and Profinet, optical vs. electrical communication links, overcoming bandwidth limitations using digital signal processing.
Recommendations
Interest in communications engineering, networking, and photonics

Literature
Ivan Kaminow, Tingye Li, Alan E. Willner (Editors), Optical Fiber Telecommunications (Sixth Edition), Elsevier
Rajiv Ramaswami, Kumar N. Sivarajan and Galen H. Sasaki, Optical Networks (Third Edition), Elsevier

Workload
total 120 h, hereof 30 h lecture, 15 h problems class and 75 h recapitulation and self-studies
Module: Adaptive Optics  [M-ETIT-103802]

Responsibility: Ulrich Lemmer

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Optical Systems

ECTS

Identifier Course ECTS Responsibility
T-ETIT-107644 Adaptive Optics 3 Ulrich Lemmer

Learning Control / Examinations
Type of Examination: Oral examination
Duration of Examination: 30 Minutes
Modality of Exam: The oral exam is scheduled two weeks after WS.

Qualification Objectives
Course Description
Adaptive optics is a technology of correcting the effect of atmospheric turbulence on images of space objects and on laser beams propagating through random and highly aberrated media such as turbulence, tissue, and the inside of the human eye, to name just a few applications. The course will familiarize the students with theoretical basics of light propagation through random media, principles of wavefront sensing and reconstruction, as well as wavefront correction with deformable mirrors.

The students will also receive solid introduction to statistical optics, the Kolmogorov theory of turbulence, practical aspects of turbulence simulation and modelling of adaptive optics performance. Design of adaptive optics systems through error budget equations, simulations and analytical models will be discussed. Applications from astronomy, free-space laser communications and medicine will be given.

Learning targets
The students will:

- get familiar with Fourier description of imaging through aberrated optical systems and random media,
- understand the description of aberrations through Zernike modes,
- learn how to analytically compute the effects of turbulence on various optical observables such as image/beam motion, temporal power spectra, Zernike modes, scintillation, etc.,
- understand the effect of noise on various quantities and metrics pertinent to the design of adaptive optical systems,
- understand the advantages and disadvantages of various schemes for wavefront sensing and correction,
- learn how to simulate and design simple adaptive optics systems.

Content
1. Theory of turbulence
2. Fourier optics
3. Statistical optics
4. Sources and description of aberrations
5. Adaptive optics systems
6. Wavefront sensing
7. Wavefront correction
8. Simulation of adaptive optical systems

**Recommendations**
Fourier analysis, statistics, classical optics, probability theory

**Literature**

**Workload**
total 90 h, hereof 30 h contact hours and 60 h homework and self-studies
11.5 Specialization - Solar Energy

11.5.1 Compulsory Modules

Module: Solar Energy  [M-ETIT-100524]

Responsibility: Bryce Sydney Richards
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Solar Energy / Compulsory Modules
Additional Achievements

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Compulsory

Identifier | Course            | ECTS | Responsibility
T-ETIT-100774 | Solar Energy       | 6    | Bryce Sydney Richards

Learning Control / Examinations
Type of Examination: written exam
Duration of Examination: 120 Minutes
Modality of Exam: One written exam at the end of each semester.

Conditions
Active participation in the lectures and problem classes.

Qualification Objectives
The students:
- understand the basic working principle of pn-junction solar cells,
- learn about the different kinds of solar cells (crystalline and amorphous silicon, CIGS, Cadmium telluride, organic, dye-sensitized solar cells, etc.),
- get an overview over upcoming third-generation photovoltaic concepts,
- receive information on photovoltaic modules and module fabrication,
- develop an understanding of solar cell integration and feeding the electrical power to the grid,
- get insight into solar concentration and tandem solar cells for highly efficient energy conversion,
- compare photovoltaic energy harvesting with solar thermal technologies
- understand the environmental impact of solar energy technologies.

Die Studentinnen und Studenten können in englischer Fachsprache sehr gut kommunizieren.

Content
I. Introduction: The Sun
II. Semiconductor fundamentals
III. Solar cell working principle
IV. First Generation solar cells: silicon wafer based
V. Second Generation solar cells: thin films of amorphous silicon, copper indium gallium diselenide, cadmium telluride, organic photovoltaics and dye sensitized solar cells
V. Third Generation Photovoltaics: high-efficiency device concepts incl. tandem solar cells
VI. Modules and system integration
VII. Cell and module characterization techniques
VIII. Economics, energy pay-back time, environmental impact
IX. Other solar energy harvesting processes, incl. thermal and solar fuels
X. Excursion

Recommendations
Semiconductor fundamentals

Literature
P. Würfel: Physics of Solar Cells
V. Quaschning: Renewable Energy Systems

Workload
Total 180 h, hero of 60 h contact hours (45 h lecture, 15 h problem class), and 120 h homework and self-studies
11.5.2 Elective Modules

Module: Electric Power Generation and Power Grid (Sp-EPG) [M-ETIT-101917]

Responsibility: Bernd Hoferer

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Solar Energy / Elective Modules

Additional Achievements

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Compulsory

Learning Control / Examinations

Type of Examination: oral exam

Duration of Examination: 20 Minutes

Modality of Exam: oral exam

Conditions

none

Qualification Objectives

The students

- are familiar with characteristics of different types of power generation
- are able to evaluate the performance of different types of power generation
- comprehend the challenges in power transmission systems due to volatile power generation.
- can derive solutions for a future power generation pool and power grid
- are able to calculate the efficiency factor of power generation systems
- know how to apply mathematical concepts like load flow calculation and short-circuit calculations

Content

I. Energy resources and energy consumption
II. Conversion of primary energy in power plants; thermo-dynamical fundamental terms, processes in steam power plants; steam power plants components; flue gas cleaning
III. Synchronous machines
IV. Thermal power plants (fossil-fueled steam generation, nuclear-fueled steam generation)
V. Renewable energy generation (hydro-electric, wind, solar)
VI. Transmission systems (AC power transmission, DC power transmission)
VII. Load flow calculations

Recommendations

one

Literature

Schwab; Electric energy systems;
Fink, Beatty; Standard handbook for electrical engineers

Workload

total 90 h, hereof 30 h contact hours and 60 h homework and self-studies
## Module: Laser Materials Processing (Sp-LMP) [M-ETIT-101914]

### Responsibility:
Thomas Graf

### Organisation:
KIT-Fakultät für Elektrotechnik und Informationstechnik

### Curricular Anchorage:
Compulsory Elective

### Contained in:
- Specialization / Specialization - Optical Systems
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

### ECTS, Recurrence, Duration, Language, Version

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### Compulsory

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<td>Laser Materials Processing</td>
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<td>Thomas Graf</td>
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### Learning Control / Examinations

- **Type of Examination:** oral exam
- **Duration of Examination:** 20 Minutes
- **Modality of Exam:** Oral exams on arrangement

### Conditions
None

### Qualification Objectives
The goal of the module is to gain knowledge and understanding of the manifold applications of the laser, especially for welding, cutting, drilling, structuring, and surface treatment. The students know and understand the numerous application possibilities of the laser in welding, cutting, drilling, structuring, and surface treatment. They are able to judge and to improve the quality and efficiency of laser based processes.

### Content

I. Introduction
II. The Tool (Laser Beams, Generation of Laser Beams, Laser Beam Sources, System Engineering)
IV. The Processes (Cutting, Welding, Surface Treatments, Drilling and Structuring)

### Recommendations

Basic knowledge of physics and mathematics for the solution of simple equations

### Literature
Hügel, Graf: Laser in der Fertigung – Grundlagen der Strahlquellen, Systeme, Fertigungsverfahren, Vieweg+Teubner
ISBN: 978-3-8348-1817-1

### Workload
total 90 h, hereof 21h contact hours, and 79h homework and self-studies
Module: Research Project [M-PHYS-102194]

Responsibility: Heinz Kalt
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Biomedical Photonics / Elective Modules
Specialization / Specialization - Optical Systems
Specialization / Specialization - Solar Energy / Elective Modules
Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-PHYS-103632 Research Project 4 Heinz Kalt

Contents

Learning Control / Examinations
The date of the project work is to be fixed individually. The format can be:
- a 1.5 week block course in the semester break
- a consecutive work of 4h/week during the entire semester

A written report of about 10 pages (at the discretion of the supervisor) concludes the Research Project. The overall performance of the students will be graded. The mark and the allocated 4CP are optional part of the elective courses in the specialization direction.

Conditions
None.

Qualification Objectives
The Research Project augments the theoretical knowledge acquired in the elective lecture courses by application to hands-on research in the respective KSOP research area. Hereby the student will also explore possible topics for the subsequent master thesis.

The students
- get in-depth insight into a special research topic
- get hands-on experience in experimental and/or theoretical techniques
- learn how to obtain and evaluate relevant scientific literature
- get first experience on how to plan and organize a research project
- learn how to write a scientific report has the possibility to explore a topic for her/his Master’s Thesis

Content
The 3rd semester Research Project is optional, but highly recommended for students not working in a KSOP institute as research assistants. Accordingly, the topics of the Research Projects are provided by the KSOP PIs on an individual basis. The projects are supposed to complement the set of elective lecture courses within the specialization area of the student. The topics of the Research Projects are constantly adapted to the current research within KSOP.

Recommendations
Basic background in optics and photonics.

Literature
Literature is provided by the supervisors of the individual projects.
Workload

total 120 h, hereof 60 h contact hours (supervised research) and 60 h preparation of report and self-studies
Module: Advanced Optical Materials (6) [M-PHYS-102196]

Responsibility: Martin Wegener

Organisation: KIT-Fakultät für Physik

Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

Compulsory

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Identifier Course ECTS Responsibility
T-PHYS-102280 Advanced Optical Materials 6 Martin Wegener

Learning Control / Examinations
Type of Examination: Written examination
Duration of Examination: 120 Minutes
Modality of Exam: The written examination is scheduled for the beginning of the semester break after the end of the winter term.

Conditions
None

Content
I. Introduction (Maxwell’s equations, phenomenological material models, principles of optical waveguiding)
II. Photonic Crystals (Photonic bandstructures, 1D-, 2D-, 3D- photonic crystals, Defects, Numerical Methods, Photonic crystal fibers)
III. Plasmonics (Surface Plasmons, Metallic nanoparticles, optical Antennas, plasmon waveguides)
IV. Metamaterials (Negative index materials, transformation optics, microwave and photonic metamaterials, 3D metamaterials)
V. Integrated Optical Circuits (optical waveguides, nonlinear optical materials, tunable optical devices)

Recommendations
Basic background in physics, solid background in optics and photonics.

Literature

Workload
total 180 h, hereof 60 h contact hours (45 h lecture, 15 h problems class), and 120 h homework and self-studies
M Module: Solid-State Optics, without Exercises (6) [M-PHYS-102408]

Responsibility: Michael Hetterich

Organisation: KIT-Fakultät für Physik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Solar Energy / Elective Modules

Compulsory Achievements:

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Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 45 minutes
Modality of Exam: Appointments for the oral exam can be made individually with the lecturer.

Conditions
None

Qualification Objectives
The students

- know the basic interaction processes between light and matter and are familiar with the polariton concept
- can explain the optical properties of insulators, semiconductors (including quantum structures), and metals
- comprehend the concept of the dielectric function and can utilize it to calculate relevant optical quantities (reflectance etc.)
- are familiar with the classical Drude–Lorentz model and its implications for the optical properties of insulators and metals (e.g., resulting dispersion, longitudinal and transverse eigenfrequencies, Reststrahlen bands, plasma frequency, etc.)
- understand the relation between classical and quantum-mechanical models for the dielectric function (e.g., concerning the oscillator strength) as well as the importance of the Kramers–Kronig relations
- can explain near band-edge spectra (absorption, reflection, luminescence) of semiconductors and insulators based on the concepts of joint density of states, oscillator strength, as well as excitonic effects
- are familiar with experimental techniques for the measurement of optical functions like grating/prism monochromators, set-ups for absorption, reflectance and luminescence measurements, basics of ellipsometry, Fourier, Raman, and modulation spectroscopy
- understand the origin of different optical nonlinearities and high-excitation effects as well as their mathematical description
- know the most important nonlinear optical effects (e.g., second-harmonic generation, parametric amplification, etc.), the problems involved (e.g., phase matching, choice of materials) and can apply their knowledge
- comprehend the basics of group theory and can apply it to solid-state optics, e.g., for the derivation of optical selection rules
Content
Maxwell’s equations, refractive index, dispersion, dielectric function, extinction, absorption, reflection, continuity conditions at interfaces, anisotropic media and layered systems, Drude–Lorentz model, reststrahlen bands, Bloch states and band structure, perturbation theory of light–matter interaction, band to band transitions, joint density of states, van Hove singularities, phonon and exciton polaritons, plasmons, metals, semiconductor heterostructures, low-dimensional systems, group theory and selection rules, nonlinear optics, high-excitation effects in semiconductors, measurement of optical functions: Fourier spectroscopy, ellipsometry, modulation spectroscopy, photoluminescence, reflectometry, absorptivity.

Recommendations
Basic knowledge in solid-state physics, optics, electrodynamics, and quantum-mechanics, solid mathematical background.

Literature
C. Klingshirn: Semiconductor Optics (Springer)
H. Ibach and H. Lüth, Solid-State Physics

Workload
total 180 h, hereof 90 h contact hours (lectures), and 90 h recapitulation and self-studies
Module: Plastic Electronics / Polymerelectronics  [M-ETIT-100475]

Responsibility: Ulrich Lemmer
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Optical Systems
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100763 Plastic Electronics / Polymerelectronics 3 Ulrich Lemmer

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 20 min
Modality of Exam: Oral exam (20 minutes)

Conditions
None.

Qualification Objectives
To enquire during lecture.

Content
1. Introduction
2. Electronic Structure of organic (macro) molecules
3. Optical properties of organic semiconductors
4. electronic transport
5. Light emitting diodes
6. organic solid state lasers
7. Xerography
8. Photovoltaic cells
9. Organic field effect transistors
10. Organic electroluminescent displays
11. Device fabrication

Recommendations
None.

Literature
The corresponding documents are available online in the VAB (https://studium.kit.edu/)

Workload
total 90 h, hereof 30 h lecture, and 60 h recapitulation and self-studies
Module: Nano-Optics (6) [M-PHYS-102146]

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**Learning Control / Examinations**

- **Type of Examination:** Oral exam
- **Duration of Examination:** 30 minutes
- **Modality of Exam:** oral exam

**Conditions**

None

**Qualification Objectives**

- improve their understanding of general principles in electrodynamics and optics
- have a deeper understanding of the theoretical background in optical imaging and its relation to phenomena on a nanoscale
- are familiar with conventional techniques in optical microscopy and make use of their knowledge for the understanding of nano-optical methods
- realize the necessity of completely new experimental concepts to overcome the constraints of classical microscopy in the exploration of optical phenomena beyond the diffraction limit
- understand the basics of different experimental approaches for optical imaging on a nanoscale
- are able to discuss pros and cons of these techniques for applications in different fields of physics and biology
- are aware of the importance of nano-optical methods for the elucidation of long-standing interdisciplinary issues

**Content**

The lecture gives an introduction to theory and instrumentation of advanced methods in optical microscopy. Emphasis is laid on far- and near-field optical techniques with an optical resolution capability on a 10- to 100-nm-scale which is well below the principal limit of classical microscopy. Applications from different scientific disciplines are discussed (e.g., nano-antennas, single-molecule detection, plasmon-polariton propagation on metal surfaces, imaging of biological cell compartments including membranes).

**Recommendations**

Solid mathematical background, basics of classical optics

**Literature**

Will be mentioned in the lecture.

**Workload**

total 180 h, hereof 60 h contact hours (45 h lecture, 15 h problems class) and 120 h homework and self-studies
Module: Computational Photonics, without ext. Exercises  [M-PHYS-103089]

Responsibility: Carsten Rockstuhl
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Optical Systems
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

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**Learning Control / Examinations**
Type of Examination: Programming assignment and oral presentation
Duration of Examination: 30 Minutes
Modality of Exam: One month before the end of the lecture period we distribute selected programming task from the field of computational photonics, which we ask you to solve at home. You will be fully prepared in the labwork course to solve those tasks. The examination then consists of an oral presentation at the end of the lecture period. There, you shall discuss the mathematical and physical background, shall outline implementation details and strategies for the problem you was assigned to, and shall present the results of a computation. You should also do a live simulation demonstration to convince your colleagues and us that the program was property implemented.

**Conditions**
None.

**Qualification Objectives**
The students shall learn how to use a computer to solve optical problems and how to visualize details of light-matter-interaction to obtain unprecedented insights, shall appreciate different strategies used to solve Maxwell’s equations, shall understand how spatial symmetries and the arrangement of matter in space can be used to formulate Maxwell’s equations such that they are amenable for a numerical solution, shall be able to implement programs by themselves at the end of the course which they can use in their on-going studies, shall learn how to use a computer to discuss and to explore physical phenomena in general and optical in specific, and shall be familiar with basic computational strategies that emerge in photonics, but comparably in any other scientific discipline.

**Content**
Transfer Matrix Method to describe the optical response from stratified media, Finite Differences to characterize eigenmode in fiber waveguides, Beam propagation method to describe the evolution of light in the realm of integrated optics, Grating methods to predict reflection and transmission from periodically arranged material in 1D and 2D, Mie Theory to describe the scattering of light from individual cylindrical or spherical objects, Finite-Difference Time-Domain method as a general purpose tool to solve micro- and nanooptical problems, Multiple Multipole Method as an approach to describe light scattering from single objects with an arbitrary shape, Greens’ Methods to discuss equally the scattering from single objects but embedded in an inhomogeneous background, Boundary Integral Method to discuss scattering from objects highly efficient using expressions for the fields on the surface.

**Recommendations**
Solid mathematical background, good knowledge of classical electromagnetism and optics, exposure to basic aspects of computational physics, foremost: interest in doing work numerically.
Literature
“Classical Electrodynamics” John David Jackson,
“Theoretical Optics: An Introduction” Hartmann Römer,
“Principles of Optics” M. Born and E. Wolf,
“Computational Electro-magnetics: The Finite-Difference Time Domain Method,” A. Taflov and S. C. Hagness,
“Light Scattering by Small Particles”, H. C. van de Hulst.

Workload
total 120 h, hereof 45 h contact hours, (30 h lecture, 15 h labwork class), and 75 h homework and self-studies
Module: Solar Thermal Energy Systems (Sp-STES) [M-MACH-101924]

Responsibility: Ron Dagan

Organisation: KIT-Fakultät für Maschinenbau

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Solar Energy / Elective Modules

Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-MACH-106493 Solar Thermal Energy Systems 3 Ron Dagan

Learning Control / Examinations

Type of Examination: oral exam
Duration of Examination: 30 Minutes
Modality of Exam: oral exam

Conditions
None

Qualification Objectives

The students
get familiar with the global energy demand and the role of renewable energies
learn about improved designs for using efficiently the potential of solar energy
gain basic understanding of the main thermal hydraulic phenomena which support the work on future innovative applications
will be able to evaluate quantitatively various aspects of the thermal solar systems

Content

I. Introduction to solar energy: Energy resources, consumption and costs
II. The sun as an energy resource:
Structure of the sun, Black body radiation, solar constant, solar spectral distribution
Sun-Earth geometrical relationship
III. Passive and active solar thermal applications.
IV. Fundamentals of thermodynamics and heat transfer
V. Solar thermal systems - solar collector-types, concentrating collectors, solar towers. Heat losses and efficiency
VI. Energy storage
The course deals with fundamental aspects of solar energy. Starting from a global energy panorama the course deals with the sun as a thermal energy source. In this context, basic issues such as the sun’s structure, blackbody radiation and solar–earth geometrical relationship are discussed. In the next part, the lectures cover passive and active thermal applications and review various solar collector types including concentrating collectors and solar towers and the concept of solar tracking. Further, the collector design parameters determination is elaborated, leading to improved efficiency. This topic is augmented by a review of the main laws of thermodynamics and relevant heat transfer mechanisms.
The course ends with an overview on energy storage concepts which enhance practically the benefits of solar thermal energy systems.

Literature

Foster, Ghassemi, cota.; Solar Energy
Duffie and Beckman; Solar engineering of thermal processes
Holman.; Heat transfer
Heinzel; script to solar thermal energy (in German)
Workload
Total 90 h, hereof 30 h contact hours and 60 h homework and self-studies
12 Additional Achievements

Module: Laser Physics [M-ETIT-100435]

Responsibility: Christian Koos
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Optical Systems
- Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100741 Laser Physics 4 Christian Koos

Learning Control / Examinations
Type of Examination: Oral examination
Duration of Examination: 30 minutes
Modality of Exam: The oral exam is scheduled for the beginning of the break after the WS.

Conditions
No formal prerequisites. However, steady participation in lecture and tutorial as well as thorough preparation based on the scriptum is highly recommended.

Qualification Objectives
The students
- know the fundamental relations and background of lasers
- gain the necessary knowledge for understanding and dimensioning of lasers, laser media, optical resonators and pump strategies
- understand the pulse generation with lasers and their fundamental relations
- obtain the necessary knowledge on several lasers; gas-, solid state, fiber- and disc-lasers in the visible and middle infrared range

Content
1 Quantum-mechanical fundamentals of lasers
1.1 Einstein relations and Planck ’s law
1.2 Transition probabilities and matrix elements
1.3 Mode structure of space and the origin of spontaneous emission
1.4 Cross sections and broadening of spectral lines
2 The laser principles
2.1 Population in version and feedback
2.2 Spectroscopic laser rate equations
2.3 Potential model of the laser
3 Optical Resonators
3.1 Linear resonators and stability criterion
3.2 Mode structure and intensity distribution
3.3 Line width of the laser emission
4 Generation of short and ultra-short pulses
4.1 Basics of Q-switching
4.2 Basics of mode locking and ultra-short pulses
5 Laser examples and their applications
5.1 Gas lasers: The Helium-Neon-Laser
5.2 Solid-state lasers
5.2.1 The Nd\textsuperscript{3+}-Laser
5.2.2 The Tm\textsuperscript{3+}-Laser
5.2.3 The Ti\textsuperscript{3+}:Al\textsubscript{2}O\textsubscript{3} Laser
5.3 Special realisations of lasers
5.3.1 Thermal lensing and thermal stress
5.3.2 The fiber laser
5.3.3 The thin-dis laser

Recommendations
Solid mathematical background, basic knowledge in physics

Literature
M. Eichhorn, Laser physics (Springer)
M. Eichhorn, Laserphysik (Springer)
A. E. Siegman, Lasers (University Science Books)
B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics (Wiley-Interscience)
F. K. Kneubühl, M. W. Sigrist, Laser (Teubner)

Workload
total 120 h, hereof 45 h contact hours (30 h lectures, 15 h tutorial) and 75 h recapitulation and self-studies
Module: Optical Transmitters and Receivers  [M-ETIT-100436]

Responsibility: Wolfgang Freude

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Additional Achievements

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Compulsory

Identifier | Course | ECTS | Responsibility |
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T-ETIT-100639 | Optical Transmitters and Receivers | 4 | Wolfgang Freude |

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 Minutes
Modality of Exam: Oral examination, usually one examination day per month during the Summer and Winter terms. An extra questions-and-answers session will be held if students wish so.

Conditions
Exercise sheet can be downloaded as homework each week. Active participation in the problem classes is advised. Studying in learning groups is strongly recommended.

Qualification Objectives
The students
understand the peculiarities of optical communications, and how optical signals are generated, transmitted and received,
know about sampling, quantization and coding,
learn the basics about noise on reception,
understand the properties of a linear and a nonlinear optical fibre channel,
grasp the idea of channel capacity and spectral efficiency,
know about various forms of modulation,
acquire knowledge of optical transmitter elements,
understand the function of optical amplifiers,
have a basic understanding of optical receivers,
know the sensitivity limits of optical systems, and
understand how these limits are measured.

Content
The course concentrates on basic optical communication concepts and connects them with the properties of physical components. The following topics are discussed:

- Advantages and limitations of optical communication systems
- Optical transmitters comprising lasers and modulators
- Optical receivers comprising direct and heterodyne reception
- Characterization of signal quality

Recommendations
Minimal background required: Calculus, differential equations, Fourier transforms and p-n junction physics
Literature
Detailed textbook-style lecture notes can be downloaded from the IPQ lecture pages.
Electronic version available via w.freude@kit.edu.

Workload
total 120 h, hereof 33 h contact hours, (15 x 1.5 h = 22h lecture, 15 x 0.75 h = 11 h problem class), and 97 h homework and self-studies
Module: Optical Waveguides and Fibers  [M-ETIT-100506]

Responsibility: Christian Koos
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Additional Achievements

ECTS | Recurrence | Duration | Language | Version
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4 | Each winter term | 1 term | English | 1

Compulsory

Identifier | Course | ECTS | Responsibility
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T-ETIT-101945 | Optical Waveguides and Fibers | 4 | Christian Koos

Learning Control / Examinations
Type of Examination: Oral
Duration of Examination: 20 Minutes
Modality of Exam: The written exam is offered continuously upon individual appointment.

Conditions
There are no prerequisites for participating in the examination.
There is, however, a bonus system based on the problem sets that are solved during the tutorials: During the term, 3 problem sets will be collected in the tutorial and graded without prior announcement. If for each of these sets more than 70% of the problems have been solved correctly, a bonus of 0.3 grades will be granted on the final mark of the oral exam.

Qualification Objectives
The students

- conceive the basic principles of light-matter-interaction and wave propagation in dielectric media and can explain the origin and the implications of the Lorentz model and of Kramers-Kronig relation,
- are able to quantitatively analyze the dispersive properties of optical media using Sellmeier relations and scientific databases,
- can explain and mathematically describe the working principle of an optical slab waveguide and the formation of guided modes,
- are able to program a mode solver for a slab waveguide in Matlab,
- are familiar with the basic principle of surface plasmon polariton propagation,
- know basic structures of planar integrated waveguides and are able to model special cases with semi-analytical approximations such as the Marcatili method or the effective-index method,
- are familiar with the basic concepts of numerical mode solvers and the associated limitations,
- are familiar with state-of-the-art waveguide technologies in integrated optics and the associated fabrication methods,
- know basic concepts of state-of-the-art waveguide technologies in integrated optics and the associated fabrication methods,
- are able to derive and solve basic relations for step-index fibers from Maxwell’s equations,
- are familiar with the concept of hybrid and linearly polarized fiber modes,
- can mathematically describe signal propagation in single-mode fibers design dispersion-compensated transmission links,
- conceive the physical origin of fiber attenuation effects,
- are familiar with state-of-the-art fiber technologies and the associated fabrication methods,
- can derive models for dielectric waveguide structures using the mode expansion method,
- conceive the principles of directional couplers, multi-mode interference couplers, and waveguide gratings,
- can mathematically describe active waveguides and waveguide bends.
Content

1. Introduction: Optical communications
2. Fundamentals of wave propagation in optics: Maxwell’s equations in optical media, wave equation and plane waves, material dispersion, Kramers-Kroig relation and Sellmeier equations, Lorentz and Drude model of refractive index, signal propagation in dispersive media.
3. Slab waveguides: Reflection from a plane dielectric boundary, slab waveguide eigenmodes, radiation modes, inter- and intramodal dispersion, metal-dielectric structures and surface plasmon polariton propagation.
4. Planar integrated waveguides: Basic structures of integrated optical waveguides, guided modes of rectangular waveguides (Marcatili method and effective-index method), basics of numerical methods for mode calculations (finite difference- and finite-element methods), waveguide technologies in integrated optics and associated fabrication methods
5. Optical fibers: Optical fiber basics, step-index fibers (hybrid modes and LP-modes), graded-index fibers (infinitely extended parabolic profile), microstructured fibers and photonic-crystal fibers, fiber technologies and fabrication methods, signal propagation in single-mode fibers, fiber attenuation, dispersion and dispersion compensation.
6. Waveguide-based devices: Modeling of dielectric waveguide structures using mode expansion and orthogonality relations, multimode interference couplers and directional couplers, waveguide gratings, material gain and absorption in optical waveguides, bent waveguides

Recommendations
Solid mathematical and physical background, basic knowledge of electrodynamics

Literature
B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics
G.P. Agrawal: Fiber-optic communication systems
C.-L. Chen: Foundations for guided-wave optics
Katsunari Okamoto: Fundamentals of Optical Waveguides
K. Iizuka: Elements of Photonics

Workload
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial) and 75 h homework and self-studies.
## Module: Field Propagation and Coherence [M-ETIT-100566]

**Responsibility:** Wolfgang Freude  
**Organisation:** KIT-Fakultät für Elektrotechnik und Informationstechnik  
**Curricular Anchorage:** Compulsory Elective  
**Contained in:**  
- Specialization / Specialization - Photonic Materials and Devices  
- Specialization / Specialization - Optical Systems  
- Additional Achievements

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### Learning Control / Examinations

**Type of Examination:** oral exam  
**Duration of Examination:** 30 Minutes  
**Modality of Exam:** Oral examination, usually one examination day per month during the summer and winter terms. An extra questions-and-answers session will be held for preparation if students wish so.

### Conditions

There are no prerequisites, but solution of the problems on the exercise sheet, which can be downloaded as homework each week, is highly recommended. Also, active participation in the problem classes and studying in learning groups are strongly advised.

### Qualification Objectives

Presenting in a unified approach the common background of various problems and questions arising in general optics and optical communications

The students

- know the common properties of counting of modes, density of states and the sampling theorem
- comprehend the relationship between propagation in multimode waveguides, mode coupling, MMI and speckles
- can analyze propagation in homogeneous media with respect to system theory, antennas, and the resolution limit of optical instruments
- understand that coherence as a general concept comprises coherence in time, in space and in polarization
- comprehend the implication of complete spatial incoherence, and what is the radiation efficiency of a source with a diameter smaller than a wavelength (the mathematical Hertzian dipole, for instance)
- can assess when can two incandescent bulbs form an interference pattern in time
- know under which conditions a heterodyne radio receiver, which is based on a non-stationary interference, actually works

### Content

The following selection of topics will be presented:

- Light waves, modes and rays: Longitudinal and transverse modes, sampling theorem, counting and density of modes (“states”)  
- Propagation in homogeneous media: Resolution limit. Non-paracial and paracial optics. Gaussian beam. ABCD matrix

Recommendations
Minimal background required: Calculus, differential equations and Fourier transform theory. Electrodynamics and field calculations or a similar course on electrodynamics or optics is recommended.

Literature
Detailed lecture notes as well as the presentation slides can be downloaded from the IPQ lecture pages. Additional reading:
Hecht, E.: Optics, 2. Ed. Reading: Addison-Wesley 1974
Further textbooks in German (also in electronic form) can be named on request.

Workload
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies
Module: Advanced Optical Materials (6) [M-PHYS-102196]

Responsibility: Martin Wegener
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Solar Energy / Elective Modules
Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-PHYS-102280 Advanced Optical Materials 6 Martin Wegener

Learning Control / Examinations
Type of Examination: Written examination
Duration of Examination: 120 Minutes
Modality of Exam: The written examination is scheduled for the beginning of the semester break after the end of the winter term.

Conditions
None

Content
I. Introduction (Maxwell's equations, phenomenological material models, principles of optical waveguiding)
II. Photonic Crystals (Photonic bandstructures, 1D-, 2D-, 3D- photonic crystals, Defects, Numerical Methods, Photonic crystal fibers)
III. Plasmonics (Surface Plasmons, Metallic nanoparticles, optical Antennas, plasmon waveguides)
IV. Metamaterials (Negative index materials, transformation optics, microwave and photonic metamaterials, 3D metamaterials)
V. Integrated Optical Circuits (optical waveguides, nonlinear optical materials, tunable optical devices)

Recommendations
Basic background in physics, solid background in optics and photonics.

Literature

Workload
total 180 h, hereof 60 h contact hours (45 h lecture, 15 h problems class), and 120 h homework and self-studies
### Module: Research Project [M-PHYS-102194]

**Responsibility:** Heinz Kalt  
**Organisation:** KIT-Fakultät für Physik  
**Curricular Anchorage:** Compulsory Elective  
**Contained in:**  
- Specialization / Specialization - Photonic Materials and Devices  
- Specialization / Specialization - Advanced Spectroscopy  
- Specialization / Specialization - Biomedical Photonics / Elective Modules  
- Specialization / Specialization - Optical Systems  
- Specialization / Specialization - Solar Energy / Elective Modules  
- Additional Achievements

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**Identifier** | **Course** | **ECTS** | **Responsibility**  
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T-PHYS-103632 | Research Project | 4 | Heinz Kalt

**Learning Control / Examinations**  
The date of the project work is to be fixed individually. The format can be:  
- a 1.5 week block course in the semester break  
- a consecutive work of 4h/week during the entire semester  

A written report of about 10 pages (at the discretion of the supervisor) concludes the Research Project. The overall performance of the students will be graded. The mark and the allocated 4CP are optional part of the elective courses in the specialization direction.

**Conditions**  
None.

**Qualification Objectives**  
The Research Project augments the theoretical knowledge acquired in the elective lecture courses by application to hands-on research in the respective KSOP research area. Hereby the student will also explore possible topics for the subsequent master thesis.  
The students  
- get in-depth insight into a special research topic  
- get hands-on experience in experimental and/or theoretical techniques  
- learn how to obtain and evaluate relevant scientific literature  
- get first experience on how to plan and organize a research project  
- learn how to write a scientific report has the possibility to explore a topic for her/his Master’s Thesis

**Content**  
The 3rd semester Research Project is optional, but highly recommended for students not working in a KSOP institute as research assistants. Accordingly, the topics of the Research Projects are provided by the KSOP PIs on an individual basis. The projects are supposed to complement the set of elective lecture courses within the specialization area of the student. The topics of the Research Projects are constantly adapted to the current research within KSOP.

**Recommendations**  
Basic background in optics and photonics.

**Literature**  
Literature is provided by the supervisors of the individual projects.
**ADDITIONAL ACHIEVEMENTS**

**Workload**

total 120 h, hereof 60 h contact hours (supervised research) and 60 h preparation of report and self-studies
Module: Solid-State Optics, without Exercises (6) [M-PHYS-102408]

Responsibility: Michael Hetterich
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective
Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-PHYS-104773 Solid-State Optics, without Exercises 6 Michael Hetterich

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 45 minutes
Modality of Exam: Appointments for the oral exam can be made individually with the lecturer.

Conditions
None

Qualification Objectives
The students

- know the basic interaction processes between light and matter and are familiar with the polariton concept
- can explain the optical properties of insulators, semiconductors (including quantum structures), and metals
- comprehend the concept of the dielectric function and can utilize it to calculate relevant optical quantities (reflectance etc.)
- are familiar with the classical Drude–Lorentz model and its implications for the optical properties of insulators and metals (e.g., resulting dispersion, longitudinal and transverse eigenfrequencies, Reststrahlen bands, plasma frequency, etc.)
- understand the relation between classical and quantum-mechanical models for the dielectric function (e.g., concerning the oscillator strength) as well as the importance of the Kramers–Kronig relations
- can explain near band-edge spectra (absorption, reflection, luminescence) of semiconductors and insulators based on the concepts of joint density of states, oscillator strength, as well as excitonic effects
- are familiar with experimental techniques for the measurement of optical functions like grating/prism monochromators, set-ups for absorption, reflectance and luminescence measurements, basics of ellipsometry, Fourier, Raman, and modulation spectroscopy
- understand the origin of different optical nonlinearities and high-excitation effects as well as their mathematical description
- know the most important nonlinear optical effects (e.g., second-harmonic generation, parametric amplification, etc.), the problems involved (e.g., phase matching, choice of materials) and can apply their knowledge
- comprehend the basics of group theory and can apply it to solid-state optics, e.g., for the derivation of optical selection rules
Content
Maxwell’s equations, refractive index, dispersion, dielectric function, extinction, absorption, reflection, continuity conditions at interfaces, anisotropic media and layered systems, Drude–Lorentz model, reststrahlen bands, Bloch states and band structure, perturbation theory of light–matter interaction, band to band transitions, joint density of states, van Hove singularities, phonon and exciton polaritons, plasmons, metals, semiconductor heterostructures, low-dimensional systems, group theory and selection rules, nonlinear optics, high-excitation effects in semiconductors, measurement of optical functions: Fourier spectroscopy, ellipsometry, modulation spectroscopy, photoluminescence, reflectometry, absorptivity.

Recommendations
Basic knowledge in solid-state physics, optics, electrodynamics, and quantum-mechanics, solid mathematical background.

Literature
C. Klingshirn: Semiconductor Optics (Springer)
H. Ibach and H. Lüth, Solid-State Physics

Workload
total 180 h, hereof 90 h contact hours (lectures), and 90 h recapitulation and self-studies
Module: X-Ray Optics (Sp-XRO) [M-MACH-101920]

Responsibility: Arndt Last
Organisation: Institut für Mikrostrukturtechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices

Additional Achievements

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Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 Minutes
Modality of Exam: The oral exam is scheduled individually for the beginning of the break after the WS.

Conditions
Not any.

Qualification Objectives
The students
- know the importance of X-ray optics in science and material analysis
- can describe the basic phenomena of X-ray generation, propagation and detection
- can calculate the optical path X-rays will follow
- are familiar with different types of X-ray optics
- can decide what X-ray optical component is suited best for what application
- comprehend the concepts of refraction, reflection, diffraction and absorption and are aware of their importance in X-ray optics
- know the differences between ray tracing and wave propagation methods and can assess what method is applicable in what case
- conceive manufacturing methods of X-ray optics
- know how to characterize X-ray optical components

Content
I. Introduction: Application of X-ray optics
II. X-ray generation
III. Propagation of X-rays in matter
IV. X-ray detection
V. Types of X-ray optics: reflecting, refracting, diffracting, absorbing
VI. Characteristics of X-ray optics
VII. Methods to simulate X-ray optics (ray tracing, wave propagation)
VIII. Manufacturing of X-ray optics
IX. Characterization of X-ray optics

Recommendations
Basic knowledge in optics.

Literature
A. Erko, M. Idir, Th. Krist and A. G. Michette (editors), Modern Developments in X-Ray and Neutron Optics
www.x-ray-optics.com

Workload
Total 90 h, hereof 30 h contact hours (lecture), and 60 h recapitulation, homework and self-studies
Module: Laser Metrology  [M-ETIT-100434]

Responsibility: Christian Koos

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Advanced Spectroscopy
Specialization / Specialization - Optical Systems
Additional Achievements

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**Compulsory**

**Identifier** Course ECTS Responsibility

T-ETIT-100643 Laser Metrology 3 Christian Koos

**Learning Control / Examinations**

Type of Examination: Oral examination

Duration of Examination: 30 minutes

Modality of Exam: The oral exam is scheduled for the beginning of the break after the SS

**Conditions**

No formal prerequisites. However, steady participation in the lecture as well as thorough preparation based on the scriptum is highly recommended.

**Qualification Objectives**

The students

- know the fundamental properties of laser light
- comprehend the different information accessible by laser metrology
- understand the fundamentals of different detectors and their limits for beam diagnostics
- comprehend several laser-metrological setups: Moiré, range and velocity measurements, absorption and scattering techniques.

**Content**

1. Laser diagnostics - theoretical considerations (laser beam properties, coherence, spectral emission of lasers, mode structure and selection, coherence length)
2. Metrological accessible information (propagation in homogeneous and isotropic, in inhomogeneous and in anisotropic media)
3. Beam diagnostics (photoelectric detectors, information theory, granulation properties of laser light)
4. Laser-Interferometer (fundamentals, two-beam Interferometer, interferometry applications in plasma physics, two- and multiwavelength-interferometry, laser gyroscopes)
5. Moiré technique (Moiré deflectometry, Fresnel- and Fraunhofer diffraction, applications and evaluation of the Moiré technique)
6. Laser range measurements (fundamentals, atmospheric influence on propagation, optical distance measurement techniques, accuracy, sensitivity, heterodyne detection, selected heterodyne detection schemes, tomoscopy)
7. Laser velocity measurement techniques (Doppler principle, measuring flow velocities using Doppler effect, the two-focus technique or laser anemometry; time-resolved imaging particle-trace anemometry)
8. Absorption and scattering techniques (absorption techniques, LIDARs, scattering processes in laser diagnostics, spontaneous scattering techniques, spectroscopic techniques, stimulated scattering, nonlinear optical laser light scattering techniques)
Recommendations
Solid mathematical background, basic knowledge in physics

Literature
M. Eichhorn, Laser metrology - Scriptum
A. E. Siegman, Lasers (university Science Books)
B. E. A. Saleh, M. C. Teich, Fundamentals of Photonics (Wiley-Interscience)

Workload
total 90 h, hereof 30 h contact hours (30 h lectures) and 60 h recapitulation and self-studies
Module: Nano-Optics (6) [M-PHYS-102146]

Responsibility: Andreas Naber
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Biomedical Photonics / Elective Modules
- Specialization / Specialization - Solar Energy / Elective Modules

Additional Achievements

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Compulsory

Learning Control / Examinations
Type of Examination: Oral exam
Duration of Examination: 30 minutes
Modality of Exam: oral exam

Conditions
None

Qualification Objectives
The students
- improve their understanding of general principles in electrodynamics and optics
- have a deeper understanding of the theoretical background in optical imaging and its relation to phenomena on a nanoscale
- are familiar with conventional techniques in optical microscopy and make use of their knowledge for the understanding of nano-optical methods
- realize the necessity of completely new experimental concepts to overcome the constraints of classical microscopy in the exploration of optical phenomena beyond the diffraction limit
- understand the basics of different experimental approaches for optical imaging on a nanoscale
- are able to discuss pros and cons of these techniques for applications in different fields of physics and biology
- are aware of the importance of nano-optical methods for the elucidation of long-standing interdisciplinary issues

Content
The lecture gives an introduction to theory and instrumentation of advanced methods in optical microscopy. Emphasis is laid on far- and near-field optical techniques with an optical resolution capability on a 10- to 100-nm-scale which is well below the principal limit of classical microscopy. Applications from different scientific disciplines are discussed (e.g., nano-antennas, single-molecule detection, plasmon-polariton propagation on metal surfaces, imaging of biological cell compartments including membranes).

Recommendations
Solid mathematical background, basics of classical optics

Literature
Will be mentioned in the lecture.

Workload
total 180 h, hereof 60 h contact hours (45 h lecture, 15 h problems class) and 120 h homework and self-studies
Module: Light and Display Engineering  [M-ETIT-100512]

Responsibility: Rainer Kling

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Optical Systems

Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-ETIT-100644 Light and Display Engineering 4 Rainer Kling

Learning Control / Examinations
Type of Examination: Oral exam
Duration of Examination: 25 Minutes
Modality of Exam: The oral exam is flexibly held by student request after the WS.

Conditions
None

Qualification Objectives
The students will apply their comprehensive knowledge of physics of optical phenomena to applied optical systems in light and display engineering. These applications span from human sensing with the eye to light technologies with lamps, luminaires and displays. The course gives a broad overview how optics can be applied in modern technology fields. The subjects taught are further clarified by demonstrations, models and experiments.
The students
- can derive the description of basic of light engineering starting from the eye and the visual system
- know how to handle basic metrical units and know how to measure them
- understand the visible sensing in contrast to radiation measurements
- comprehend the concepts of colour and colour control
- are familiar with all types of light sources from low pressure lamps to LED modules
- conceive the operation principle of various types of drivers
- know how to set up a luminaire and how simulate a reflector
- they understand how active (Plasma Displays) and passive displays (TFT Display) work and how to operate them
- have a good visualization of numerous optical design approaches

Content
1. Motivation: Light & Display Engineering
2. Light, the Eye and the Visual System (including Melatonin)
3. Fundamentals in Light Engineering
4. Light in non-visual Processes (UV Processes)
5. Color and Brightness
6. Light Sources (Halogen, Low Pressure and High Pressure Lamps, LED Engines) and electronic Drivers
7. Displays (Active and Passive Displays: AMOLED, E-ink, TFT Display, Plasma Display)
8. Luminaries (Fundamentals, Design Rules, Simulations)
9. Optical Design (Ray tracing, Reflector design, Computed Ray tracing)

Recommendations
Basic physics background
ADDITIONAL ACHIEVEMENTS

Literature
Shunsuke Kobayashi: LCD Backlights, 2009
Malacara, Handbook of Optical Design, 2004

Workload
total 120 h, hereof 45 h contact hours (lecture and tutorial), and 75 h homework and self-studies
**Module: Systems and Software Engineering**  [M-ETIT-100537]

**Responsibility:** Eric Sax

**Organisation:** KIT-Fakultät für Elektrotechnik und Informationstechnik

**Curricular Anchorage:** Compulsory Elective

**Contained in:** Specialization / Specialization - Optical Systems Additional Achievements

**Compulsory**

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**Identifier** | **Course** | **ECTS** | **Responsibility**
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T-ETIT-100675 | Systems and Software Engineering | 4 | Eric Sax

**Learning Control / Examinations**
Written (see actual document “Studienplan” and notice of the examination office ETIT).

**Module Grade**
Grades result from the written examination.

**Conditions**
none

**Qualification Objectives**
The students:
§ know the most important Life Cycle and process models (including V-Model and agile methods).
§ are capable of choosing a suitable method to design and evaluate complex systems.
§ know the most important diagram types of hardware and software modeling languages and can design such diagrams from characterization of an application area.
§ know the basic methods for quality assurance, which are needed during project development. They know the different test phases of a project and can evaluate the reliability of a system.
§ They are familiar with the issues of functional safety and the standards of process evaluation.

**Content**
Major topics are techniques and methods for the design of complex electric, electronic and electronic programmable systems with software fragments and hardware fragments. The competences of the course comprise comprehensive knowledge and goal-oriented usage of state of the art modeling techniques, development processes, description techniques as well as specification languages.

**Recommendations**
Participation in the lectures Digital System Design (23615) and Information Technology (23622) is advised

**Workload**
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial) and 75 h homework and self-studies
Module: Lighting Design - Theory and Applications  [M-ETIT-100577]

Responsibility: Rainer Kling
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Optical Systems

Additional Achievements

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Compulsory

Identifier: T-ETIT-100997
Course: Lighting Design - Theory and Applications
ECTS: 3
Responsibility: Rainer Kling

Learning Control / Examinations
Type of Examination: Oral exam
Duration of Examination: 25 Minutes
Modality of Exam: The oral exam is flexibly held by student request after the WS.

Conditions
None

Qualification Objectives
The students will apply a comprehensive knowledge of Lighting Design from theory, standards and applications in Indoor and Outdoor lighting. Examples and own Lighting design examples as projects. So a practical and theoretical background is applied to Lighting Design. From metrics too Light Planning projects in small exercise groups. The subjects taught are further clarified by demonstrations, models and experiments. Attending students get the knowledge to Lighting Design, in a shorter theoretical part and practical lighting design simulations with examples from all over the world.

The students

- can derive the description of basics of Lighting Design
- know how to handle basic metrical units and know how to measure them
- understand the Lighting Design metrics to apply on projects
- have a good visualization of numerous design approaches
- realize good Lighting Design with codes and standards.
- can see energy savings levels for Lighting Design
- comprehend the lighting design by practical self-computing lessons:
- can realize own indoor Lighting design concepts for different applications like Office, School, Shops, Gyms & Industry
- can realize own outdoor Lighting Design concepts for Street lighting, Tunnels, Stade and Parkings
- can use for realization Relux and Dialux light planning software so set up Project Planning for Lighting Design.

Content
1. Lighting Design - Introduction form all over the world
2. Lighting Fundamentals
3. Lighting Design Theory
4. Energy Savings and Lighting design
5. Lighting Design Tools
6. Computing Standards
7. Lighting Design Applications (Practical Part)
   7.1 Interior Lighting
   7.2 Exterior lighting
   7.3 IlluminationOwn Calculation Examples (Practical Part)

Motivation: Light & Display Engineering
8. Own Calculation Examples (Practical Part)

**Motivation:** Light & Display Engineering

**Recommendations**
Basic physics background

**Literature**
M. Karlen: Lighting Design Basics, Indoor Lightin, 2004
R.H. Simons Lighting Engineering, 2001

**Workload**
total 90 h, hereof 45 h contact hours (Seminar), and 45 h homework and self-studies
**Module: Machine Vision (Sp-MV) [M-MACH-101923]**

**Responsibility:** Martin Lauer, Christoph Stiller  
**Organisation:** KIT-Fakultät für Maschinenbau  
**Curricular Anchorage:** Compulsory Elective  
**Contained in:** Specialization / Specialization - Optical Systems  
**Additional Achievements**

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<td>Machine Vision</td>
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<td>Martin Lauer, Christoph Stiller</td>
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**Learning Control / Examinations**

- **Type of Examination:** written exam  
- **Duration of Examination:** 60 Minutes  
- **Modality of Exam:** Written exam  

**Conditions**

None.

**Qualification Objectives**

Machine vision (or computer vision) describes the computer supported solution of visual tasks similar to human vision. The technical domain of machine vision includes numerical research areas like optics, digital signal processing, 3d measurement technology, and pattern recognition. Application areas for machine vision techniques can be found in automation and control, robotics, and intelligent vehicles, among others.

The lecture introduces the basic machine learning techniques and algorithms and illustrates their use. The lecture is composed out of 3 hours/week lecture and 1 hour/week computer exercises. In the computer exercises methods introduced in the lecture will be implemented in MATLAB and tested experimentally.

**Content**

1. Overview of machine vision  
2. Image formation and image preprocessing techniques  
3. Edge detection  
4. Line and curve fitting  
5. Color representation  
6. Image segmentation  
7. Camera optics and camera calibration  
8. Illumination  
9. 3d reconstruction  
10. Pattern recognition

**Recommendations**

Solid mathematical background.

**Workload**

total 180 h, hereof 60 h contact hours (45 h lecture, 15 h computer exercises), and 120 h homework and self-studies.
Module: Solar Energy [M-ETIT-100524]

Responsibility: Bryce Sydney Richards
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Solar Energy / Compulsory Modules
Additional Achievements

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Compulsory

Identifier | Course          | ECTS | Responsibility
-----------|-----------------|------|-------------------
T-ETIT-100774 | Solar Energy    | 6    | Bryce Sydney Richards

Learning Control / Examinations
Type of Examination: written exam
Duration of Examination: 120 Minutes
Modality of Exam: One written exam at the end of each semester.

Conditions
Active participation in the lectures and problem classes.

Qualification Objectives
The students:
- understand the basic working principle of pn-junction solar cells,
- learn about the different kinds of solar cells (crystalline and amorphous silicon, CIGS, Cadmium telluride, organic, dye-sensitized solar cells, etc.),
- get an overview over upcoming third-generation photovoltaic concepts,
- receive information on photovoltaic modules and module fabrication,
- develop an understanding of solar cell integration and feeding the electrical power to the grid,
- get insight into solar concentration and tandem solar cells for highly efficient energy conversion,
- compare photovoltaic energy harvesting with solar thermal technologies
- understand the environmental impact of solar energy technologies.

Die Studentinnen und Studenten können in englischer Fachsprache sehr gut kommunizieren.

Content
I. Introduction: The Sun
II. Semiconductor fundamentals
III. Solar cell working principle
IV. First Generation solar cells: silicon wafer based
V. Second Generation solar cells: thin films of amorphous silicon, copper indium gallium diselenide, cadmium telluride, organic photovoltaics and dye sensitized solar cells
V. Third Generation Photovoltaics: high-efficiency device concepts incl. tandem solar cells
VI. Modules and system integration
VII. Cell and module characterization techniques
VIII. Economics, energy pay-back time, environmental impact
IX. Other solar energy harvesting processes, incl. thermal and solar fuels
X. Excursion

Recommendations
Semiconductor fundamentals

Optics & Photonics (M.Sc.)
Module Handbook, Date 10/06/2017, Winter term 17/18
### Literature

P. Würfel: Physics of Solar Cells  
V. Quaschning: Renewable Energy Systems  

### Workload

Total 180 h, hero of 60 h contact hours (45 h lecture, 15 h problem class), and 120 h homework and self-studies
Module: Laser Materials Processing (Sp-LMP) [M-ETIT-101914]

Responsibility: Thomas Graf
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Optical Systems, Specialization / Specialization - Solar Energy / Elective Modules, Additional Achievements

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Identifier Course ECTS Responsibility
T-ETIT-103607 Laser Materials Processing 3 Thomas Graf

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 20 Minutes
Modality of Exam: Oral exams on arrangement
Conditions
None

Qualification Objectives
The goal of the module is to gain knowledge and understanding of the manifold applications of the laser, especially for welding, cutting, drilling, structuring, and surface treatment.
The students know and understand the numerous application possibilities of the laser in welding, cutting, drilling, structuring, and surface treatment
understand which properties of the laser beam, material, and environment influence the processes in which way are able to judge and to improve the quality and efficiency of laser based processes

Content
I. Introduction
II. The Tool (Laser Beams, Generation of Laser Beams, Laser Beam Sources, System Engineering)
IV. The Processes (Cutting, Welding, Surface Treatments, Drilling and Structuring)

Recommendations
Basic knowledge of physics and mathematics for the solution of simple equations

Literature

Workload
total 90 h, hereof 21h contact hours, and 79h homework and self-studies
Module: Electric Power Generation and Power Grid (Sp-EPG) [M-ETIT-101917]

Responsibility: Bernd Hoferer

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Solar Energy / Elective Modules

Additional Achievements

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**Learning Control / Examinations**

Type of Examination: oral exam
Duration of Examination: 20 Minutes
Modality of Exam: oral exam

**Conditions**

none

**Qualification Objectives**

The students

- are familiar with characteristics of different types of power generation
- are able to evaluate the performance of different types of power generation
- comprehend the challenges in power transmission systems due to volatile power generation.
- can derive solutions for a future power generation pool and power grid
- are able to calculate the efficiency factor of power generation systems
- know how to apply mathematical concepts like load flow calculation and short-circuit calculations

**Content**

I. Energy resources and energy consumption
II. Conversion of primary energy in power plants; thermo-dynamical fundamental terms, processes in steam power plants; steam power plants components; flue gas cleaning
III. Synchronous machines
IV. Thermal power plants (fossil-fueled steam generation, nuclear-fueled steam generation)
V. Renewable energy generation (hydro-electric, wind, solar)
VI. Transmission systems (AC power transmission, DC power transmission)
VII. Load flow calculations

**Recommendations**

none

**Literature**

Schwab; Electric energy systems;
Fink, Beaty; Standard handbook for electrical engineers

**Workload**

total 90 h, hereof 30 h contact hours and 60 h homework and self-studies
Module: Plastic Electronics / Polymerelectronics [M-ETIT-100475]

Responsibility: Ulrich Lemmer

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular An-chorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Optical Systems
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

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**Learning Control / Examinations**

Type of Examination: oral exam
Duration of Examination: 20 min
Modality of Exam: Oral exam (20 minutes)

**Conditions**
None.

**Qualification Objectives**
To enquire during lecture.

**Content**

1. Introduction
2. Electronic Structure of organic (macro) molecules
3. Optical properties of organic semiconductors
4. electronic transport
5. Light emitting diodes
6. organic solid state lasers
7. Xerography
8. Photovoltaic cells
9. Organic field effect transistors
10. Organic electroluminescent displays
11. Device fabrication

**Recommendations**
None.

**Literature**
The corresponding documents are available online in the VAB (https://studium.kit.edu/)

**Workload**
total 90 h, hereof 30 h lecture, and 60 h recapitulation and self-studies
Module: Advanced Inorganic Materials (Sp-AIM) [M-CHEMBIO-101901]

Responsibility: Claus Feldmann

Organisation: KIT-Fakultät für Chemie und Biowissenschaften

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Advanced Spectroscopy
Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-CHEMBIO-103591 Advanced Inorganic Materials 3

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 min
Modality of Exam: The oral exam is scheduled at the end of the semester.

Conditions
No formal prerequisite, but continuous presence in the lecture is strongly recommended. An overall amount of 50% of the problems given in the written exam has to be solved correctly.

Qualification Objectives
The students refresh and elaborate their knowledge on inorganic materials, materials chemistry as well as basic inorganic chemistry and solid state chemistry. This comprises fundamental aspects of the chemistry of the elements as well as state-of-the-art knowledge on the synthesis, structure, properties (including optical properties) and application (including luminescence) of inorganic functional materials.

The students
- get familiar with basic inorganic chemistry and solid state chemistry
- get familiar with concepts of describing crystal structures
- know how to characterize inorganic solid compounds and materials
- learn how to prepare inorganic compounds and solid materials
- understand general aspects of structure-property relations
- comprehend general concepts of solid state chemistry and inorganic functional materials
- are able to rationalize fundamental properties of inorganic materials
- know general trends in view of a technical application of advanced inorganic materials

Content
Selected aspects of modern functional inorganic materials, including:
- High-temperature ceramics and hard materials
- Color pigments – from Egyptian blue to 2D Bragg stacks
- Phosphors, luminescence, spectroscopy
- Fast ion conductors and high-power batteries
- Superconductors: metals, alloys, oxocuprates and current developments
- Porous networks: from zeolites to metalorganic frameworks (MOFs)
- Transparent conductive oxides and dye-sensitized solar cells
- Magnetic pigments: magnetic recording, superparamagnetism and magnetothermal therapy
- Modern thermoelectric materials
- Fullerenes and fibre-reinforced composite materials

Optics & Photonics (M.Sc.)
Module Handbook, Date 10/06/2017, Winter term 17/18
• Nanomaterials: Quantum Dots, hollow spheres and nanotubes
. . . and other examples of advanced functional materials

Recommendations
Basic knowledge in chemistry

Literature
Selected reviews (as given in the lecture).

Workload
total 90 h, hereof 30 h lecture, and 90 h recapitulation and self-studies
Module: Molecular Spectroscopy (Sp-MS) [M-CHEMBIO-101902]

**Responsibility:** Manfred Kappes, Andreas-Neil Unterreiner

**Organisation:** KIT-Fakultät für Chemie und Biowissenschaften

**Curricular Anchorage:** Compulsory Elective

**Contained in:** Specialization / Specialization - Advanced Spectroscopy

**Additional Achievements**

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### Learning Control / Examinations

Type of Examination: written exam  
Duration of Examination: 120 Minutes  
Modality of Exam: The written exam is scheduled for the beginning of the break after the WS. A resit exam is offered at the end of the break. The exam consists of a set of problems that the students solve with the aid of certain allowed resources.

**Conditions**

One page of exercises is handed out to the students as homework each week. Solutions to these exercises can be presented by the students during exercises/tutorials on the blackboard on a voluntary basis. Participation in questions and answers during tutorials is strongly supported and encouraged (though not a formal requirement).

### Qualification Objectives

Students will obtain a comprehensive overview of the field of molecular spectroscopy and will learn to interpret and assign molecular spectra. Starting with the quantum mechanical foundations of light-matter interactions, selection rules and structure-dependent transition energies will be derived for rotational-, vibrational- and electronic-spectroscopy. The focus is on dipole-allowed transitions in diatomic molecules. However, students will also learn about absorption/emission in small polyatomic species. Additionally, the fundamentals of Raman scattering as well as nuclear and electron spin resonance spectroscopy will be presented.

The students

- understand and can apply the quantum mechanical description of molecular rotational, vibrational and electronic spectroscopy;
- can analyse and assign microwave, vibrational, electronic and Raman spectra of diatomic and small polyatomic molecules;
- understand the interdependence between spectroscopic method, experimental design and required optical components learn the fundamentals of electron and nuclear spin resonance spectroscopy

### Content

I. Spectroscopic fundamentals: spectral regions; conversion factors; resolution; characteristic timescales; light-matter interactions; experimental configurations;
II. Quantum-mechanical treatment of light absorption: Schrödinger equation; time-dependent perturbation theory description of transitions in a two-level system; Einstein coefficients; line profiles (lifetime broadening, Doppler- and collisional broadening); saturation;
III. Diatomic molecules: transition dipole moment formalism to calculate selection rules for harmonic oscillator and rigid rotor models, occupation numbers and transition strengths, Morse potential and Pekeris equation, vibration-rotation spectroscopy; vibrational overtones and time-independent perturbation theory; Raman effect and quantum-mechanical description; couplings and complications (nuclear spin statistics, quadratic Stark effect, rotational Zeeman effect);
IV. Polyatomic molecules: rotation in classical mechanics (moment of inertia tensor; oblate and prolate rotors; asymmet-
ric rotor); quantum-mechanical description; selection rules and correlations between symmetric and asymmetric rotors; structure determination by microwave spectroscopy; vibrations in polyatomics; degrees of freedom; Lagrangian mechanics; normal coordinates and symmetry; selection rules; GF-matrix formalism for normal coordinate analysis.

V. Introduction to electronic spectroscopy: Born-Oppenheimer approximation; Franck-Condon factors;

VI. Introduction to electron and nuclear spin resonance: basic theory and experimental setups

**Recommendations**
Basic atomic/molecular quantum mechanics, Important: indicate your intention to take this module in English by emailing the lecturer before semester begin

**Literature**
Atkins: Molecular Quantum Mechanics, P. Bernath: Spectra of Atoms and Molecules, Demtröder: Laser Spectroscopy

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies
Module: Advanced Molecular Cell Biology (Sp-AMCB) [M-CHEMBIO-101904]

Responsibility: Martin Bastmeyer, Franco Weth
Organisation: KIT-Fakultät für Chemie und Biowissenschaften
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Biomedical Photonics / Compulsory Modules

Additional Achievements

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<td>Franco Weth</td>
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Learning Control / Examinations

Type of Examination: Oral or written
Duration of Examination: 45 min (oral) or 120 min (written)
Modality of Exam: The exam will be oral or written depending on the number of course participants. The exact modality of the exam will be announced at the beginning of the semester. The exam is scheduled for the break after the WS. A resit exam will be offered when needed.

Conditions

Advanced textbook or review articles will be announced on a weekly basis. They have to be read by all participants. the contents will be discussed in the class sessions. Each class session is chaired by one participant and all participants have to contribute a sub-chapter/ figure per session. For the problems class, exercise sheets will be handed out and participants have to be prepared to present their solutions.

Qualification Objectives

The students
- are able to extract the central ideas from an advanced textbook or review article and introduce their fellow student to the topic,
- have acquire an advanced knowledge of the cell division cycle and exemplify applications of FRET for its analysis,
- understand DNA replication, recombination and repair and the basis of fluorescence based deep sequencing,
- are familiar with nuclear organization and epigenetic regulation and FISH as a means of analysing chromosomes,
- understand protein folding and degradation and discuss optical tweezers as a tool for the investigation of the folding problem,
- can address posttranslational modifications and cutting edge technologies based on fluorophore click-chemistry to observe them,
- comprehend cell suicide (apoptosis) and techniques of laser ablation to induce cell death
- are familiar with the different forms of cell/cell and cell/matrix contacts and with TIRF microscopy as a means of studying them,
- conceive the mechanisms of cell migration and their observation by live cell imaging,
- are familiar with principal mechanisms of embryonic development and understand fluorescent microarray technology for profiling the accompanying gene expression changes,
- understand the concepts of tissues, stem cells and cancer and of the quantification of gene expression by fluorescent nanostring and real-time fluorescence spectroscopy (qPCR),
- understand excitability and synaptic transmission in neurons and their observation with voltage and calcium sensitive fluorophores,
- are acquainted with the concepts of immunity and the application of antibodies in fluorescent immunoassays.
Content
Progress in no other field of science is so intimately linked to the continuing development and welfare of humanity as the achievements of the life sciences. Modern biomedical research, however, is inconceivable without cutting-edge Optics & Photonics technologies ranging from high-throughput sequencing to super-resolution microscopy. Most students of Optics & Photonics are therefore likely to get in contact with life scientists during their careers. In this course, they will prepare themselves for fruitful future collaborations, which rely on shared concepts and terminologies. To this end, students will familiarize themselves with the basic principles and ideas of Molecular Cell Biology, which is at the heart of modern Biosciences.

I. Introduction to the cell
II. Concepts from Organic Chemistry pertinent to the Life Sciences
III. Concepts from Physical Chemistry pertinent to the Life Sciences
IV. Nucleic acids and proteins
V. Gene expression
VI. Methods
VII. Genomic variability and evolution
VIII. Cell membranes
IX. Energy metabolism
X. Cell signalling
XI. Cell compartments
XII. Cytoskeleton and cell division

Recommendations
Passed exam of the Adjustment Course in “Basic Molecular Cell Biology”

Literature

Workload
Total 150 h, hereof 40 h contact hours (30 h class, 10 h problem class), and 110 h homework and self-studies
**Module: Imaging Techniques in Light Microscopy (Sp-ITL) [M-CHEMBIO-101905]**

**Responsibility:** Martin Bastmeyer

**Organisation:** KIT-Fakultät für Chemie und Biowissenschaften

**Curricular Anchorage:** Compulsory Elective

**Contained in:** Specialization / Specialization - Biomedical Photonics / Elective Modules

**Additional Achievements**

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**Learning Control / Examinations**

**Type of Examination:** Oral or written exam

**Duration of Examination:** 45 min (oral) or 120 min (written)

**Modality of Exam:** Depending on the number of participants, an oral or written exam is accomplished. The exact modality of the exam will be announced at the beginning of the semester. The written exam is scheduled for the beginning of the break after the WS. A resit exam is offered at the end of the break.

**Conditions**

Attendance to the lecture.

**Qualification Objectives**

The students

- are able to derive the description of geometric- and wave-optical principles of a compound microscope
- know the physical principles of fluorescent dyes
- understand the configuration of laser scanning microscopes
- comprehend digital imaging and image processing
- have experienced a hands on laboratory praxis of the different microscopic techniques
- understand the biological principles of GFP-expression
- know the latest developments in light microscopy
- understand how technical development of microscopes has driven basic biological research

**Content**

This lecture series is designed to gain familiarity with fundamentals of biological light microscopy and modern fluorescence techniques. Depending on the content, the students will have lab demonstrations of different microscopes or imaging techniques covered in the lecture.

I. Introduction (History and Basic Principles of Compound Microscopes, Resolution and Contrast, Biological Sample Preparation)

II. Imaging Modes and Contrast Techniques (Biological Amplitude and Phase Objects, Phase Contrast, Interference Contrast, Polarization Microscopy)

III. Fluorescence Microscopy (Microscopic Principles, Fluorescent Dyes and Proteins, Biological Sample Preparation)

IV. Laser-Scanning-Microscopy (Basic Principles, Spinning Disk, 2-Photon Microscopy, Optical Sectioning Techniques)

V. Live Cell Imaging (Video Microscopy, Fluorescent Proteins)

VI. Special Fluorescence Techniques (FRET, TIRF, FCS)

VII. Special Resolution Microscopy (SIM, PALM, dSTORM, STED)

VII. Digital Images (Image Processing, Data Analysis and Quantification)

**Recommendations**

Basic knowledge in physics and biology
ADDITIONAL ACHIEVEMENTS

Literature
Lecture presentations will be accessible in pdf-format
Recent review articles will be distributed before the lectures
Books:
Alan R. Hibbs: Confocal Microscopy for Biologists, Springer Press
Rafael Yuste (Ed.): Imaging, a laboratory manual, CSH Press
James Pawley: Handbook of biological confocal microscopy, Plenum Press

Workload
Total 90 h, hereof 30 h contact hours (30 h lecture), and 60 h homework and self-studies
Module: Optics and Vision in Biology (Sp-OVB) [M-CHEMBIO-101906]

Responsibility: Martin Bastmeyer

Organisation: KIT-Fakultät für Chemie und Biowissenschaften

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Biomedical Photonics / Elective Modules Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility

T-CHEMBIO-105198 Optics and Vision in Biology 4 Martin Bastmeyer

Learning Control / Examinations

Type of Examination: Written exam

Duration of Examination: 120 Minutes

Modality of Exam: The written exam is scheduled for the break after the WS. A resit exam will be offered, when needed.

Conditions

Attendance to the lecture.

Qualification Objectives

The students

- understand the anatomy and optics of the vertebrate eye and its aberrations
- comprehend retinal microanatomy and its relation to retinal computation
- are familiar with the wiring of the retinofugal pathways in vertebrates
- know their roles in circadian rhythm, pupillary reflex and gaze control
- conceive the details of higher visual processing in the thalamocortical pathway
- know how cortical processing achieves visual scene segmentation and feature binding
- understand the psychophysics of the perception of brightness, color, shape, depth and motion
- are acquainted with the different types of eyes in lower animals
- can distinguish microvillated and ciliated photoreceptors
- are able to analyse the function of compound eyes and the insect visual system
- can conceptualize the molecular details of phototransduction in the different types of photoreceptors
- understand the quantum bump as the signature of single-photon sensitivity
- comprehend microbial light sensing and its influence on circadian clocks, phototropism, reproduction
- know the underlying phytochromes and associated proteins
- understand how light can regulate gene expression in microorganisms
- have grasped the mechanisms of green plant photosynthesis
- conceive the structure and function of chloroplasts, antenna complexes and photosystems
- have conceptualized the underlying energy transfer cascades, electron transport chain as well as the Calvin cycle of carbon fixation
- comprehend the light path in leaves
- know the Kautsky effect involving fluorescence and photosynthesis
- understand the advantages and disadvantages of biofuels
- are familiar with the principles of optogenetics as a means to genetically engineer organisms to induce light sensitivity.

Content

Evolution has developed abundant ways of harnessing light for the benefits of life. Through plant photosynthesis, life manifestations of all higher species are powered by solar energy. Light sensing has evolved a bewildering variety of forms
ranging from light control of reproduction, germination, development in microorganisms to sophisticated visual processing in higher animals. In this course, students will develop a conceptual understanding of the overwhelming importance of light in these natural biological processes. Learning from nature might enable them in the future to generate novel ideas for technological applications of light, ranging from sustainable energy conversion to computer vision.

I. The vertebrate eye and retina  
II. Central visual pathways in vertebrates  
III. Visual processing and perception in the human cortex  
IV. Invertebrate eyes – evolution, architecture and function  
V. Phototransduction  
VI. Microbial phytochromes and light sensing  
VII. Photosynthesis  
VIII. Optogenetics

Recommendations  
Passed exam of the Adjustment Course in “Basic Molecular Cell Biology” AdjC-BMCB.

Literature  
Lecture presentations are provided in pdf-format  
Neuroscience, Purves, D. et al., Sinauer, 2011  

Workload  
Total 120 h, hereof 40 h contact hours and 80 h homework and self-studies
Module: Organic Photochemistry (Sp-OPC) [M-CHEMBIO-101907]

Responsibility: Hans-Achim Wagenknecht
Organisation: KIT-Fakultät für Chemie und Biowissenschaften
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Biomedical Photonics / Elective Modules

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Compulsory

Identifier Course ECTS Responsibility
T-CHEMBIO-105195 Organic Photochemistry 3

Learning Control / Examinations
Type of Examination: Oral exam
Duration of Examination: 30 min
Modality of Exam: The written exam is scheduled for the beginning of the break after the WS. A resit exam is offered at the end of the break.

Conditions
No formal prerequisite, but participation in the lecture is highly recommended.

Qualification Objectives
The students learn the principles of organic photochemistry. This includes the knowledge about the photochemical reactivity of functional groups in organic compounds, photocatalysis and applications in synthesis and bioorganic chemistry. The students
- Can draw reaction mechanism of organic photochemical reactions
- Know the difference of direct excitation of organic functional groups vs. photocatalysis
- Know the photophysics of excitation of organic chromophores and the major decay pathways
- Can relate structure of functional groups to photochemical reactivity and organic synthesis
- Know difference of photoinduced electron transfer and energy transfer to induce organic reactions
Know the special significance of visible light excitation

Content
1. Photophysical basics
2. Organic photochemistry
   2.1 Principles
   2.2 Photoadditions
   2.3 Photolyses
   2.4 Photoisomerization and molecular switches
3. Photocatalysis
   3.1 Flavin photocatalysis
   3.2 Template photocatalysis
   3.3 Introduction in photoredox catalysis
   3.4 Photoredox organic catalysis
   3.5 Water splitting
4. Bioorganic photochemistry
   4.1 Photocleavable groups
   4.2 Photoaffinity labeling
   4.3 Singlet oxygen, photodynamic therapy and chemiluminescence
4.4 Photoinduced electron transfer in DNA

Recommendations
Solid background in organic chemistry.

Literature

Workload
total 90 h, hereof 30 h contact hours (lecture) and 60 h recapitulation and self-studies
Module: Optical Systems in Medicine and Life Science  [M-ETIT-103252]

**Responsibility:** Werner Nahm

**Organisation:** KIT-Fakultät für Elektrotechnik und Informationstechnik

**Curricular Anchorage:** Compulsory Elective

**Contained in:** Specialization / Specialization - Biomedical Photonics / Elective Modules

Specialization / Specialization - Optical Systems

Additional Achievements

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**Identifier** | **Course** | **ECTS** | **Responsibility**
---|---|---|---
T-ETIT-106462 | Optical Systems in Medicine and Life Science | 3 | Werner Nahm

**Learning Control / Examinations**

Type of Examination: Results of 4 case studies (protocols & presentations)

Modality of Exam: The examination is the presentation of the 4 case works by the team plus the written protocol of the case work including the required documentation.

**Module Grade**

The grade is calculated from the presentations and protocols of 3 case studies and one hands-on experience.

**Conditions**

None

**Qualification Objectives**

Students have formulated use cases and requirements for complex medical devices from different perspectives: user, system engineer, development engineer.

Students have systematically broken down complex systems to functional components. The underlying physics and physiology have been described in detail.

Students have explained and operated the systems and evaluated the results.

Students have identifies new technical solutions based on current problem descriptions. They have prepared development plans for implementing product improvements into the product life cycle.

Students have contributed to their team with their creativity, technical know-how, and personal working style. Thy have presented and defended team results as well as own contributions.

**Content**

Part 1:

Case study: Basics
- Fields of application for optical systems in medicine and life sciences
- Physical and physiological basics
- Basics for complex systems development

Part 2:

Case study: Systems and components
- System design and system architecture
- Component design and functionality

Part 3:

Hands-on experience

Part 4:

Case study: System Enhancements
Recommendations
None

Remarks
Language English

Literature
M. Kaschke, Optical Devices in Ophthalmology and Optometry, Wiley-VCH

Workload
total 90 h, hereof 30 h contact hours and 60 h homework and self-studies
Module: German at ID A1.1 (AKC-GLC) [M-IDSCHOOLS-102198]

Responsibility: Miriam Sonnenbichler

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Additive Key Competences

Additional Achievements

ECTS
Recurrence
Duration
Language
Version
4
Each winter term
1 term
German
2

Compulsory

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Learning Control / Examinations

Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 90 Minutes
Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

Conditions
Regular attendance (80%), active participation in class; presentation; successful completion of written homework and tests during the lecture period

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), B3 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course conveys first competencies on level A1 of GER:
Can understand and use familiar everyday expressions and very basic phrases aimed at the satisfaction of needs of a concrete type. Can introduce him/herself and others and can ask and answer questions about personal details such as where he/she lives, people he/she knows and things he/she has. Can interact in a simple way provided the other person talks slowly and clearly and is prepared to help.

Content
Cultural Studies:
1. Introducing oneselfs and others, greetings and farewells, when to use du and Sie
2. German across Europe
3. Punctuality, leisure activities, german cuisine
4. Public transport, festivals in the german speaking countries

Spoken and written interaction:
greeting someone, initiating a conversation, introducing oneself and others, asking for somebody’s name and where she/he is from, spelling, ordering and paying drinks, understanding and giving phone numbers, naming and asking for things in...
ADDITIONAL ACHIEVEMENTS

the classroom, talking about countries and cities, their geographical locations and sights, the languages spoken there, describing a diagram, writing little texts about oneself, describing a flat, understanding and telling time, describing one's daily routine, making appointments and dates, apologizing for being late, telling where people work and live, telling how people get to work, in a big building: asking for people and directions, setting up appointments on the phone

Grammar:
Verbs in german, present tense, present tense verb conjugation, irregular and regular verbs, nouns, prepositions bei, als, in, aus, grammatical person in plural, negation nicht, numbers, word order in statements, ja-nein-doch, verbs with a vowel change, possessiv pronouns, definite article der, die, das, personal pronouns er, es, sie, prices, particle denn, indefinite artikel ein, eine, negative article kein/e, singular and plural, accusative, modal auxiliaries and sentences brackets, modal auxiliary können, irregular verbs with vowel changes, expressing astonishment and approval, telling the time, word formation

Learning techniques:
identify international words, classify words, use flashcards and "phrase boxes", use dictionaries, complete or formulate own grammar rules, develope grammar tables, note taking strategies, use wordnets

Recommendations
No previous knowledge of the German language required, but strong motivation and readiness for autonomous language learning, as a language portfolio has to be kept.

Literature
Coursebook:

Workbook:

Workload
total 120h, here of 45h contact hours, 75h homework and self-study and preparation for exam
**Module: German at ID A1.2 (AKC-GLC) [M-IDSCHOOLS-102281]**

**Responsibility:** Tina Krebs

**Organisation:** KIT-Fakultät für Elektrotechnik und Informationstechnik

**Curricular Anchorage:** Compulsory Elective

**Contained in:** Additive Key Competences, Additional Achievements

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**Learning Control / Examinations**

Type of Examination: 70% written exam, 30% spoken performance  
Duration of Examination: 90 Minutes  
Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

**Conditions**

Regular attendance (80%), active participation in class, successful completion of written homework and tests during the lecture period.

**Qualification Objectives**

This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency).

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course completes competencies on level A1 of GER:  
The students can understand and use familiar everyday expressions and very basic phrases aimed at the satisfaction of needs of a concrete type. Can introduce him/herself and others and can ask and answer questions about personal details such as where he/she lives, people he/she knows and things he/she has. Can interact in a simple way provided the other person talks slowly and clearly and is prepared to help.

**Content**

**Cultural Studies:**
1. ask for and give route descriptions, living in German cities  
2. make appointments, speak about arches and pains  
3. character traits, rules in household and society  
4. evaluate: clothes, weather, celebrations

**Spoken and written interaction:**

Institutions and places in town, apartments and houses, being hotel, plans and wishes, human body, appearance, character, everyday household tasks, traffic rules, environment, clothing, weather, cardinal points, celebrations.
Grammar:

Recommendations
Successful completion of A1.1 and a strong motivation and readiness for autonomous language learning

Literature
Coursebook:

Workbook:

Dictionary:
Bilingual dictionary

Workload
total 120 h, hereof 45 h contact hours, 75 h homework and self-studies and preparation for exam
Module: German at ID A2.1  [M-IDSCHOOLS-102357]

Responsibility: Miriam Sonnenbichler

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Additive Key Competences
Additional Achievements

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Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 90 Minutes
Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

Conditions
Regular attendance (80%), active participation in class; presentation; successful completion of written homework and tests during the lecture period

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course conveys first competencies on level A2 of GER:
The students can understand sentences and frequently used expressions related to areas of most immediate relevance (e.g. very basic personal and family information, shopping, local geography, employment). Can communicate in simple and routine tasks requiring a simple and direct exchange of information on familiar and routine matters. Can describe in simple terms aspects of his/her background, immediate environment and matters in areas of immediate need.

Content
Cultural Studies:
1. handle relocation
2. manage to buy food
3. handling of topics like health, sport and spa in German culture
4. being in restaurant

Spoken and written interaction:
family, activities, events, institutions, relocations, nature, landscapes, foodstuff, packages, weights, tourism, events, sports, illnesses, accidents, being in restaurants, commodities
**ADDITIONAL ACHIEVEMENTS**

**Grammar:**
subjunctive I, reflexive verbs, perfect, past tense of: *sein* + *haben*, word creation: suffix -er + -ung, adjective declination, after articles, possessive article in different cases, changing prepositions, verbs with changing prepositions, temporal prepositions, temporal adverbs, conjunctions: *weil*, *deshalb*, *dass*, *wenn*

**Recommendations**
Successful completion of A1.2 and a strong motivation and readiness for autonomous language learning

**Literature**

**Coursebook:**

**Workbook:**

**Dictionary:**
Bilingual dictionary

**Workload**
total 120h, hereof 45h contact hours, 75h homework and self-study and preparation for exam
Module: German at ID B1.1  [M-IDSCHOOLS-102359]

Responsibility: Miriam Sonnenbichler
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Additive Key Competences, Additional Achievements

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Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 90 Minutes
Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

Conditions
Regular attendance (80%), active participation in class; presentation; successful completion of written homework and tests during the lecture period

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)
This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.
The language course conveys first competencies on level B1 of GER:
The students can understand the main points of clear standard input on familiar matters regularly encountered in work, school, leisure, etc. Can deal with most situations likely to arise whilst travelling in an area where the language is spoken. Can produce simple connected text on topics which are familiar or of personal interest. Can describe experiences and events, dreams, hopes and ambitions and briefly give reasons and explanations for opinions and plans.

Content
Cultural Studies:
1. building the language conditions to make friends
2. German service behavior
3. career choice and possibilities in Germany
4. understanding of joy and luck in different cultures

Spoken and written interaction:
traits, work, living, customer service, media, technique, invitations for dinner, animals, advices, strenghts, weaknesses, health, doing sport, nutrition, breakdowns in everyday life, moments of happiness, events in companies
Grammar:
infinite with zu, subjunctive II, comparative, superlative, declination in genitive, preposition: trotz, past tense, future I, pluperfect with: sein + haben, word creation: adjectives as nouns, n-declination, relative clauses, relative clauses with prepositions, conjunctions: obwohl, trotzdem, falls, da während, bevor, nachdem

Recommendations
Successful completion of A2.2 and a strong motivation and readiness for autonomous language learning

Literature
Coursebook:

Workbook:

Dictionary:
Bilingual dictionary

Workload
total 120h, hereof 45h, contact hours, 75h homework and self-study and preparation for exam
Module: German at ID A2.2 (AKC-GLC) [M-IDSCHOOLS-103208]

Responsibility: Tina Krebs
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Additive Key Competences, Additional Achievements

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Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 90 Minutes
Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

Conditions
Regular attendance (80%), active participation in class, presentation, successful completion of written homework and tests during the lecture period

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Master or proficiency)
This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.
The language course completes competencies on level A2 of GER:
The students can understand sentences and frequently used expressions related to areas of most immediate relevance (e.g. very basic personal and family information, shopping, local geography, employment). Can communicate in simple and routine tasks requiring a simple and direct exchange of information on familiar and routine matters. Can describe in simple terms aspects of his/her background, immediate environment and matters in areas of immediate need.

Content
Cultural Studies:
1. German press + media
2. culture Events in different countries
3. cities and City Administration in Germany
4. mobility + traffic in Germany

Spoken and written interaction:
study tips, post, media, being in hotel, travels, traffic, weather, events, press, books, documents, internet/online registrations, schools, education + training, mobility, foreign countries
ADDITIONAL ACHIEVEMENTS

Grammar:
question articles, demonstrative pronouns, passive in present tense, verbs in different cases, verbs with prepositions in
different cases, modal verbs in past tense, past tense, local prepositions: gegenüber von, an...vorbei, durch, conjunctions:
bis, seit, positions of objects, indirect questions, question- and prepositional adverbs

Recommendations
Successful completion of A2.1 and a strong motivation and readiness for autonomous language learning

Literature
Coursebook:
978-3-19-301902-8

Workbook:
978-3-19-311902-5

Dictionary:
Bilingual dictionary

Workload
total 120h, here of 45h contact hours, 75h homework and self-study and preparation for exam
Module: Automotive Vision  [M-MACH-102693]

Responsibility: Martin Lauer, Christoph Stiller

Organization: KIT-Fakultät für Maschinenbau

Curricular Anchorage: Compulsory Elective

Contained in: Specialization / Specialization - Optical Systems

Additional Achievements

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Compulsory

Identifier  Course  ECTS  Responsibility
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T-MACH-105218  Automotive Vision  6  Martin Lauer, Christoph Stiller

Learning Control / Examinations
Type of Examination: Written exam
Duration of Examination: 60 Minutes
Modality of Exam: One written exam offered at the end of each semester.

Conditions
None

Qualification Objectives
Machine perception and interpretation of the environment forms the basis for the generation of intelligent behavior. Especially visual perception opens the door to novel automotive applications. Driver assistance systems already improve safety, comfort and efficiency in vehicles. Yet, several decades of research will be required to achieve an automated behavior with a performance equivalent to a human operator. The lecture addresses students in mechanical engineering and related subjects who intend to get an interdisciplinary knowledge in a state-of-the-art technical domain. Machine vision and advanced information processing techniques are presented to provide a broad overview on seeing vehicles. Application examples from cutting-edge and future driver assistance systems illustrate the discussed subjects. The lecture consists out of 2 hours/week of lecture and 1 hour/week of computer exercises. In the computer exercises methods introduced in the lecture will be implemented in MATLAB and tested experimentally.

Content
1. Basics of machine vision
2. Binocular vision
3. Feature point methods
4. Optical flow
5. Object tracking and motion estimation
6. Self-localization and mapping
7. Road recognition
8. Behavior recognition

Recommendations
None, but knowledge in Machine Vision is useful.

Workload
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h computer exersice) and 75 h homework and self-studies
Module: Advanced Lithography for Biophotonic & Optofluidic Applications
[M-MACH-103126]

Responsibility: Timo Mappes
Organisation: Institut für Mikrostrukturtechnik
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Biomedical Photonics / Elective Modules
Specialization / Specialization - Optical Systems
Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-MACH-106206 Advanced Lithography for Biophotonic & Optofluidic Applications 3 Timo Mappes

Type of Examination: oral exam
Duration of Examination: 20 Minutes
Modality of Exam: The oral exam is by appointment.

Conditions
None

Qualification Objectives
While fulfilling the learning targets, the students are familiar with the working principle of scanning electron microscopes and their similarity to electron beam lithography, including electron sources and machine types. They understand secondary effects and can develop solutions how to avoid those for lithography. They understand the working principle of focussed ion beam machines and their application in fabrication, preparation and (correlative) microscopy.

are familiar with the processes required for multi-photon-lithography in resist and glass as well as their application for (hybrid) optofluidic and biophotonic systems.
understand the physical effects in advanced immersion and next generation lithography, in particular EUV lithography know how to evaluate a new lithographical method and may elaborate on its probability to be introduced in mass fabrication. In particular, they have a good understanding of the challenges in microfabrication, including the strategies to avoid pattern defects like e.g. structure collapse
understand the applicative needs and technical production prerequisites for the generation of scaffolds to be used as tools for the study of cell clusters e.g. in biology and medicine
are familiar with the realization of optofluidic systems to be used for integrated sensing, light guiding and tailored particle fabrication

Content
This module is introducing the application of advanced lithographic patterning for applications in optofluidics and biophotonics. With an overview on typical applications of micro optical and nano photonic systems, the challenges of lithographic patterning for their fabrication are motivated. The fabrication chain for high-end structures covering is discussed, starting from electron beam machines and their similarities to scanning electron microscopes. The available and the perspective for new and novel processes of parallel and serial lithography are discussed. The working principles of lithography machines as well as their limitations are presented. Aspects for masked-based optical lithography and multi-photon lithography in a broad range of materials are elaborated on. The challenges for resolution enhancement with immersion lithography are discussed by a problem-based learning approach. Subsequently the numerous technological
(including source and beam-shaping) and economic implications of the introduction of extreme ultra violet (EUV) lithography are discussed. In order to consolidate the interrelations of the individual process steps, the micro fabrication of (hybrid) optofluidic and biophotonic systems are discussed in detail. The particular boundary conditions to enable the application of those systems in biology and medicine as well as in sensing and imaging are elaborated on.

**Recommendations**
Basic knowledge in physics.

**Literature**
References to journal publications during the lecture

**Workload**
total 90 h, hereof 30 contact hours (30 h lecture), and 60 h homework and self-studies
**Module: Computational Photonics, without ext. Exercises [M-PHYS-103089]**

**Responsibility:** Carsten Rockstuhl

**Organisation:** KIT-Fakultät für Physik

**Curricular Anchorage:** Compulsory Elective

**Contained in:**
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Optical Systems
- Specialization / Specialization - Solar Energy / Elective Modules
- Additional Achievements

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**Learning Control / Examinations**

Type of Examination: Programming assignment and oral presentation

Duration of Examination: 30 Minutes

Modality of Exam: One month before the end of the lecture period we distribute selected programming task from the field of computational photonics, which we ask you to solve at home. You will be fully prepared in the labwork course to solve those tasks. The examination then consists of an oral presentation at the end of the lecture period. There, you shall discuss the mathematical and physical background, shall outline implementation details and strategies for the problem you was assigned to, and shall present the results of a computation. You should also do a live simulation demonstration to convince your colleagues and us that the program was properly implemented.

**Conditions**

None.

**Qualification Objectives**

The students shall learn how to use a computer to solve optical problems and how to visualize details of light-matter-interaction to obtain unprecedented insights, shall appreciate different strategies used to solve Maxwell’s equations, shall understand how spatial symmetries and the arrangement of matter in space can be used to formulate Maxwell’s equations such that they are amenable for a numerical solution, shall be able to implement programs by themselves at the end of the course which they can use in their ongoing studies, shall learn how to use a computer to discuss and to explore physical phenomena in general and optical in specific, and shall be familiar with basic computational strategies that emerge in photonics, but comparably in any other scientific discipline.

**Content**

Transfer Matrix Method to describe the optical response from stratified media, Finite Differences to characterize eigenmode in fiber waveguides, Beam propagation method to describe the evolution of light in the realm of integrated optics, Grating methods to predict reflection and transmission from periodically arranged material in 1D and 2D, Mie Theory to describe the scattering of light from individual cylindrical or spherical objects, Finite-Difference Time-Domain method as a general purpose tool to solve micro- and nanooptical problems, Multiple Multipole Method as an approach to describe light scattering from single objects with an arbitrary shape, Greens’ Methods to discuss equally the scattering from single objects but embedded in an inhomogeneous background, Boundary Integral Method to discuss scattering from objects highly efficient using expressions for the fields on the surface.

**Recommendations**

Solid mathematical background, good knowledge of classical electromagnetism and optics, exposure to basic aspects of computational physics, foremost: interest in doing work numerically.
ADDITIONAL ACHIEVEMENTS

Literature
“Classical Electrodynamics” John David Jackson,
“Theoretical Optics: An Introduction” Hartmann Römer,
“Principles of Optics” M. Born and E. Wolf,
“Computational Electro-magnetics: The Finite-Difference Time Domain Method,” A. Tafløv and S. C. Hagness,
“Light Scattering by Small Particles”, H. C. van de Hulst.

Workload
total 120 h, hereof 45 h contact hours, (30 h lecture, 15 h labwork class), and 75 h homework and self-studies
Module: Quantum Optics [M-PHYS-103093]

Responsibility: Carsten Rockstuhl
Organisation: KIT-Fakultät für Physik
Curricular Anchorage: Compulsory Elective

Contained in:
- Specialization / Specialization - Photonic Materials and Devices
- Specialization / Specialization - Advanced Spectroscopy
- Specialization / Specialization - Optical Systems
- Additional Achievements

ECTS 4
Recurrence Irregular
Duration 1 term
Language English
Version 1

Learning Control / Examinations
Type of Examination: Written or oral examination
Duration of Examination: 90 minutes (written), 30 minutes (oral)
Modality of Exam: There will be a written or an oral examination, depending on the number of participants. This will be settled after the end of the fourth lecture. The written examination lasts for 90 minutes and shall be written without any supporting documents. The oral examination will last for 30 minutes.

Conditions
A minimum amount of correct solutions of the exercises that are biweekly distributed. Details will be announced in the lecture.

Qualification Objectives
The students shall learn to appreciate that quantum optics has been a framework to understand properties of light, which can by no means described with a classical theory, shall learn how to apply various methods from quantum mechanics to specific situation of quantum optics in general and to the description of the light-matter-interaction in specific, shall learn that there are fascinating opportunities to study with micro- and nano-optical systems various quantum optical phenomena, and shall appreciate that even though much of the current research is done out of intellectual curiosity, there are many application perspectives that promise to have a notable impact to our daily life.

Content
- Quantization of the electromagnetic field
- Various quantum states of light fields: optical photon-number, coherent, squeezed, Schrödinger’s cat states
- Classical and quantum coherence theory: photon bunching and antibunching
- Quantum description of optical interferometry: Mach-Zehnder interferometer with photons
- General description of open quantum system: master equation, Heisenberg-Langevin, and stochastic approaches
- Optical test of quantum mechanics: Hong-Ou-Mandel, quantum eraser, and Bell’s theorem experiments
- Interaction of a single atom with a classical field and quantum field
- From Rabi model to Jaynes-Cummings model: the most simplest model to describe the light-matter interaction
- Quantum master equation approach: description of finite life time of atoms
- Weak and strong couplings (spontaneous emission, Purcell effect, resonance fluorescence, lasers, and Rabi oscillation)
- Interaction of an ensemble of atoms with a quantum field (Dicke and Tavis-Cummings models, and superradiance)
- Quantum optical applications (quantum cryptography, quantum teleportation, quantum metrology, etc.)

Recommendations
Solid mathematical background, good knowledge of classical electromagnetics and optics, very good knowledge of quantum mechanics, foremost: interest in doing theoretical work

Optics & Photonics (M.Sc.)
Module Handbook, Date 10/06/2017, Winter term 17/18
**Literature**
C. Gerry and P. Knight, *Introductory Quantum Optics*.
M. O. Scully and M. S. Zubairy, *Quantum Optics*.
M. Fox, *Quantum Optics: An Introduction*.
R. Loudon, *The Quantum Theory of Light*.
D.F. Walls and G. J. Milburn, *Quantum Optics*.
W. Schleich, *Quantum Optics in Phase Space*.

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial), and 75 h homework and self-studies
Module: Business Innovation in Optics and Photonics [M-ETIT-101834]

Responsibility: Werner Nahm

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Additive Key Competences Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility

T-ETIT-104572 Business Innovation in Optics and Photonics 4 Olaf Dössel, Werner Nahm

Learning Control / Examinations

Type of Examination: Case study Presentation

Duration of Examination: 60 Minutes

Modality of Exam: The exam is a presentation of the case work by the team in front of the KIT lecturer and the R&D and innovation managers of the Carl Zeiss AG. Also a presentation on the group work on technical aspects earlier in the course is taken into account for the examination.

Qualification Objectives

The student has an understanding how innovative concepts for optical and photonics products are transferred into a successful business development. The student knows about and makes first hands on experiences on business development aspects in a technology start up environment. The students acquire specialized knowledge in technologies and applications in the field of smart mobile solutions for optical applications as well as an introduction into the field of patent rights. The students can organize themselves in groups and distribute and execute tasks. Further they gain competences in the fields teamwork, organization and communication.

The students

- understand the implications of intellectual property
- are able to perform database research
- know how to develop a business plan
- get an understanding of how to design a project
- are able to develop in small groups innovative business cases for a potential future product

Content

This course is instructed and presented by external innovation specialists of the R&D, business and management departments of the Carl Zeiss AG.

- Introduction: Examples of existing smart mobile device applications, Brainstorming for ideas
- Technology Introduction: Mobile device technology, Optic components, Display technology (LCD, OLED), Tracking and Sensor Technologies in smart mobile devices
- Group Work Technology
- Group Presentations Technology
- Business Case Development/ Business Plan: Market segmentation, Market research, Essentials of finance, How to write a business plan?
- Project Design: How to run an agile R&D Project?, Traget costing, Networked product development
- Agile project simulation
• Group Work
• Excursion to Carl Zeiss AG in Oberkochen (full day)
• Presentation of results of the group work to the new business experts committee of the Carl Zeiss AG

Recommendations
Personal motivation and interest for getting deeper into business development aspects, methods and tools. Commitment to active, regular and continuous participation in the group work.

Workload
total 120 h, thereof 34 h contact hours and 86 h preparation, homework, self-studies and excursion
Module: Solar Thermal Energy Systems (Sp-STES) [M-MACH-101924]

Responsibility: Ron Dagan
Organisation: KIT-Fakultät für Maschinenbau
Curricular Anchorage: Compulsory Elective
Contained in: Specialization / Specialization - Solar Energy / Elective Modules Additional Achievements

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Compulsory

Identifier | Course | ECTS | Responsibility
---|--------|------|------------------
T-MACH-106493 | Solar Thermal Energy Systems | 3 | Ron Dagan

Learning Control / Examinations
Type of Examination: oral exam
Duration of Examination: 30 Minutes
Modality of Exam: oral exam
Conditions
None

Qualification Objectives
The students
get familiar with the global energy demand and the role of renewable energies
learn about improved designs for using efficiently the potential of solar energy
gain basic understanding of the main thermal hydraulic phenomena which support the work on future innovative applications
will be able to evaluate quantitatively various aspects of the thermal solar systems

Content
I. Introduction to solar energy: Energy resources, consumption and costs
II. The sun as an energy resource:
Structure of the sun, Black body radiation, solar constant, solar spectral distribution
Sun-Earth geometrical relationship
III. Passive and active solar thermal applications.
IV. Fundamentals of thermodynamics and heat transfer
V. Solar thermal systems - solar collector-types, concentrating collectors, solar towers. Heat losses and efficiency
VII. Energy storage
The course deals with fundamental aspects of solar energy. Starting from a global energy panorama the course deals with the sun as a thermal energy source. In this context, basic issues such as the sun’s structure, blackbody radiation and solar–earth geometrical relationship are discussed. In the next part, the lectures cover passive and active thermal applications and review various solar collector types including concentrating collectors and solar towers and the concept of solar tracking. Further, the collector design parameters determination is elaborated, leading to improved efficiency. This topic is augmented by a review of the main laws of thermodynamics and relevant heat transfer mechanisms. The course ends with an overview on energy storage concepts which enhance practically the benefits of solar thermal energy systems.

Literature
Foster, Ghassemi, cota.; Solar Energy
Duffie and Beckman; Solar engineering of thermal processes
Holman.; Heat transfer
Heinzl; script to solar thermal energy (in German)
Workload
Total 90 h, hereof 30 h contact hours and 60 h homework and self-studies
Module: German at ID B1.2  [M-IDSCHOOLS-103230]

Responsibility: Tina Krebs
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Additive Key Competences
Additional Achievements

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<td>German at ID B1.2 - Exam</td>
<td>4</td>
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Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 90 Minutes
Modality of Exam: The written exam is scheduled for the end of each lecture period. 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation.

Conditions
Regular attendance (80%), active participation in class; presentation; successful completion of written homework and tests during the lecture period.

Qualification Objectives
This course is designed to assist students in developing basic German language skills, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency).

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course completes competencies on level B1 of GER:
The students can understand the main points of clear standard input on familiar matters regularly encountered in work, school, leisure, etc. Can deal with most situations likely to arise whilst travelling in an area where the language is spoken. Can produce simple connected text on topics which are familiar or of personal interest. Can describe experiences and events, dreams, hopes and ambitions and briefly give reasons and explanations for opinions and plans.

Content
Cultural Studies:
1. how to apply in Germany
2. politics and German politicians
3. brief introduction to German History
4. German environmental behavior

Spoken and written interaction:
synonyms, continuing education, applications, memories of relations, art, painting, politics, society, landscape, tourism, guestbook entry, concerts, events, history, environment, climate, future visions
Grammar:
established terms with es, nicht/nur brauchen + infinitive with zu, passive in present, past tense and perfect, passive and modal verbs, causal prepositions with genitive, local prepositions, temporal prepositions, conjunctions: causes and consequences, two-part conjunctions, funds and results, main and subordinate clause, subjunctive II, darum, deshalb, deswegen, aus diesem Grund, daher, sowohl...als auch, nicht nur...sondern auch, entweder...oder, weder...noch, zwar...aber, je...desto/umso..., indem..., sodass, (an)statt/ohne dass, damit/um...zu, als ob, word creation: partizip I+II as adjective, suffix -heit/-keit, -ismus, -ler, -ieren, -ant, -ent, adverbs: reasons and consequences, modal particles: denn, doch, eigentlich, ja

Recommendations
Successful completion of B1.1 and a strong motivation and readiness for autonomous language learning.

Literature
Coursebook:

Workbook:

Dictionary:
Bilingual dictionary

Workload
total 120 h, hereof 45 h contact hours, 75 h homework and self-studies and preparation for exam.
Module: German at ID B2.1 (AKC-GLC) [M-IDSCHOOLS-103533]

Responsibility: Tina Krebs

Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik

Curricular Anchorage: Compulsory Elective

Contained in: Additive Key Competences

Additional Achievements

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Compulsory

Identifier Course ECTS Responsibility
T-IDSCHOOLS-107057 German at ID B2.1 - Exam 4 Tina Krebs

Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 120 Minutes
Modality of Exam: 70% written exam in the end of the lecture period, 30% vrebal exam: active participation during the lessons and a presentation

Conditions
Regular attendance ( 80%), active participation in class; presentation; successful completion of written homework and tests during the lecture period.

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)

This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.

The language course conveys competencies on level B2 of GER.

By the end of this course, students will be able to understand the main ideas of complex text on both concrete and abstract topics, including technical discussions in his/her field of specialisation. Can interact with a degree of fluency and spontaneity that makes regular interaction with native speakers quite possible without strain for either party. Can produce clear, detailed text on a wide range of subjects and explain a viewpoint on a topical issue giving the advantages and Independent disadvantages of various options.

Content
Cultural Studies:
1. Comparing different cultural phenomena and regarding their influence on language
2. German working live
3. modern families and Relationship models
4. Universities in Germany

Spoken and written interaction:
Correct use of German idioms
Terminology in different incidents, specialized language
Focus on the role of grammar structures to underline a statement
Language tools to set differentiated thesis

Grammar:
fixed unit of nouns with prepositions and nouns with verbs, subjective significance of: sollen, nominalizations of verbs, various connectors, word creation, negation through word creation, alternatives for passive, forms of passive, participle I+II as adjective, reference words, wenn+dass sentences, temporal expressions

Learning techniques:
work with authentic texts, videos and listening texts, discussions - set up own theses, create written statements

Recommendations:
the German level B1.2 should be fulfilled and there should be a strong motivation and readiness for autonomous language learning, as a language portfolio has to be kept.

Recommendations
Successful completion of B1.2 and a strong motivation and readiness for autonomous language learning

Literature

Coursebook:

Dictionary:
Bilingual dictionary

Workload
total 120 h, hereof 45 h contact hours, 75 h homework and self-studies and preparation for exam
Module: German at ID B2.2 (AKC-GLC) [M-IDSCHOOLS-103536]

Responsibility: Tina Krebs
Organisation: KIT-Fakultät für Elektrotechnik und Informationstechnik
Curricular Anchorage: Compulsory Elective
Contained in: Additive Key Competences
Additional Achievements

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Learning Control / Examinations
Type of Examination: 70% written exam, 30% spoken performance
Duration of Examination: 120 Minutes
Modality of Exam: 70% written exam in the end of the lecture period, 30% verbal exam: active participation during the lessons and a presentation

Conditions
Regular attendance (80%), active participation in class; presentation, successful completion of written homework and test during the lecture period

Qualification Objectives
This course is designed to assist students in developing basic German language skills in speaking, writing, listening and reading. The specific learning targets listed below are set up in accordance with the Common European Framework of Reference for Languages (CEFR) of the European Council: A1 (Breakthrough or beginner), A2 (Waystage or elementary), B1 (Threshold or intermediate), B2 (Vantage or upper intermediate), C1 (Effective Operational Proficiency or advanced), C2 (Mastery or proficiency)
This course is suited for all students/PhD students/post-docs, who wish to improve their general language skills. During the lessons, all language skills (understanding when reading, understanding when listening, written and oral communication) are trained and enhanced.
The language course conveys competencies on level B2 of GER.
By the end of this course, students will be able to understand the main ideas of complex text on both concrete and abstract topics, including technical discussions in his/her field of specialisation. Can interact with a degree of fluency and spontaneity that makes regular interaction with native speakers quite possible without strain for either party. Can produce clear, detailed text on a wide range of subjects and explain a viewpoint on a topical issue giving the advantages and Independent disadvantages of various options.

Content
Cultural Studies:
1. Comparing different cultural phenomena and regarding their influence on language
2. German working live
3. modern families and Relationship models
4. Universities in Germany

Spoken and written interaction:
Correct use of German idioms
Terminology in different incidents, specialized language
Focus on the role of grammar structures to underline a statement
Language tools to set differentiated thesis

Grammar:
fixed unit of nouns with prepositions and nouns with verbs, subjective significance of: sollen, nominalizations of verbs, various connectors, word creation, negation through word creation, alternatives for passive, forms of passive, participle I+II as adjective, reference words, wenn+dass sentences, temporal expressions

Learning techniques:
work with authentic texts, videos and listening texts, discussions - set up own theses, create written statements

Recommendations:
the German level B2.1 should be fulfilled and there should be a strong motivation and readiness for autonomous language learning, as a language portfolio has to be kept.

Recommendations
Successful completion of B2.1 and a strong motivation and readiness for autonomous language learning

Literature
Coursebook:

Dictionary:
Bilingual dictionary

Workload
total 120 h, hereof 45 h contact hours, 75 h homework and self-studies and preparation for exam

The President expressed his approval on August 04, 2015 according to Article 20, par. 2 KITG and Article 32, par. 3, clause 1 LHG.
Official Announcement

2015 Published at Karlsruhe on August 06, 2015 No. 64

Contents

Study and Examination Regulations of Karlsruhe Institute of Technology (KIT) Relating to the Master's Program "Optics & Photonics“ 399

Kindly note that the version in the German language shall be the only legally binding version. The translation into English is to be understood as a service provided for your help.
Please find the German version on the official website of KSOP.

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Preamble

Within the framework of the implementation of the Bologna Process to establish a European university area, KIT has defined the objective that studies at KIT are to be completed by the Master’s degree. Hence, KIT considers the consecutive bachelor’s and master’s programs offered by KIT to form an overall concept with a consecutive curriculum.

I. General Provisions

Article 1 - Scope
The present master’s examination regulations shall apply to the course of studies, examinations, and graduation in the master’s program of Optics & Photonics at KIT. This program is offered jointly by the KIT Department of Chemistry and Biosciences, the KIT Department of Electrical Engineering and Information Technology, the KIT Department of Mechanical Engineering, and the KIT Department of Physics.

Article 2 – Program Objective, Academic Degree
(1) During the consecutive master’s program, scientific qualifications acquired in the course of the bachelor’s program shall be further enhanced, increased, extended, or complemented. By means of the program, students are to acquire the capability of independently applying scientific findings and methods and evaluating their significance and applicability to the solution of complex scientific and social problems.

(2) Upon successful completion of the master’s examination, the academic degree of “Master of Science (M. Sc.)” in Optics & Photonics shall be conferred.

Article 3 - Regular Period of Studies, Organization of Studies, Credits
(1) The regular period of studies shall be four semesters.

(2) The program offered is divided into subjects and subjects are divided into modules that consist of courses of studies. The subjects and their scopes are outlined in Article 19. Details are given in the module manual.

(3) The workload envisaged for passing studies courses and modules is expressed in credits. The criteria for assigning credits correspond to the European Credit Transfer System (ECTS). One credit corresponds to a workload of about 30 hours. As a rule, the credits shall be distributed equally over the semesters.

(4) The study and examination achievements required for the successful completion of the studies are measured in credits and amount to a total of 120 credits.

(5) The courses of studies are offered in the English language.
Article 4 - Module Examinations, Study and Examination Achievements

(1) The master’s examination shall consist of module examinations. Module examinations consist of one or several controls of success.

Controls of success consist of study and examination achievements.

(2) Examination achievements include:
1. Written examinations,
2. Oral examinations, or
3. Examinations of another type.

(3) Study achievements are written, oral or practical achievements that are usually made by students parallel to the studies courses. The master’s examination may not be completed by a study achievement.

(4) At least 70% of the module examinations shall be marked.

(5) In case of complementary contents, module examinations of several modules may be replaced by one module-overlapping examination (par. 2, Nos. 1 to 3).

Article 5 - Registration for and Admission to Module Examinations and Studies Courses

(1) To participate in module examinations, the students shall register online for the corresponding controls of success on the students portal (Studierendenportal). In exceptional cases, registration can be made in writing with the Students Service (Studierendenservice) or another institution authorized by the Students Service. The examiners may specify registration deadlines for the controls of success. The procedure for the registration of the master’s thesis is outlined in the module manual.

(2) If the students are free to choose, they shall submit a binding declaration on the selection of the module and its allocation to a subject together with the registration for the examination in order to be admitted to the examination. At the request of the student to the examination board, selection or allocation can be changed later on.

(3) Students shall be admitted to a control of success, if
1. they have registered for the master’s program of Optics & Photonics at KIT; students on leave of absence shall be admitted to examinations exclusively; and
2. they furnish evidence of meeting the requirements outlined in the module manual for admission to a control of success, and
3. they furnish evidence of not having lost their right to pass examinations in the master’s program of Optics and Photonics, and
4. they meet the requirement outlined in Art. 19 a.

(4) According to Art. 30, par. 5 LHG, admission to individual compulsory courses can be restricted. The examiner shall decide on the selection of students, who registered
in due time before the date fixed by the examiner taking into account the study progress of these students and taking into account Art. 13, par. 1, clauses 1 and 2, if the surplus of students registered cannot be reduced by other or additional courses. In case of the same study progress, further criteria shall be specified by the KIT departments. The students shall be informed in due time about the result.

(5) Admission shall be refused, if the requirements outlined in paragraphs 3 and 4 are not met. Admission may be refused, if the respective control of success was passed in an undergraduate bachelor's program of KIT already, which was required for admission to this master’s program. This shall not apply to so-called Mastervorzugsleistungen (achievements made during the bachelor’s program, but credited in the consecutive master’s program only). They require express approval of admission according to clause 1.

**Article 6 - Execution of Controls of Success**

(1) Controls of success shall be performed parallel to the studies, as a rule during the teaching of the syllabus of the individual modules or shortly afterwards.

(2) The type of control of success (Art. 4, par. 2, Nos. 1 – 3, par. 3) shall be specified by the examiner of the respective study course depending on the contents of the course and learning outcomes of the module. The type of the control of success, its frequency, sequence, weighing, and the determination of the module grade, if applicable, shall be announced in the module manual at least six weeks prior to the start of the semester. The examiner and student may agree on a later change of the type of examination taking into account Art. 4, par. 4 and the examination language. When organizing examinations, the interests of students with handicaps or chronic illnesses shall be taken into account according to Article 13, par. 1. Article 13, par. 1, clauses 3 and 4 shall apply accordingly.

(3) In case of an unreasonably high examination expenditure, an examination to be passed in writing may also be passed orally or an oral examination may also be passed in writing. This modification shall be announced at least six weeks prior to the examination.

(4) Controls of success shall be carried out in the English language. Article 6, par. 2 shall apply accordingly.

(5) **Written examinations** (Art. 4, par. 2, No. 1) shall usually be evaluated by one examiner according to Art. 18, par. 2 or 3. If an evaluation is made by several examiners, the grade results from the arithmetic mean of the individual marks. If the arithmetic mean does not correspond to any of the grade levels defined in Art. 7, par. 2, clause 2, it is to be rounded up or down to the nearest grade level. In case the distance to the next upper or lower grade level is the same, the grade is to be rounded up to the next better grade level. The evaluation procedure shall not exceed six weeks. Written examinations shall last at least 60 and not more than 300 minutes.

(6) **Oral examinations** (Art. 4, par. 2, No. 2) shall be performed and evaluated as individual or group examinations by several examiners (examining board) or by one
examiner in the presence of an associate. Prior to determining the grade, the examiner shall consult the other examiners of the examining board. Oral examinations shall usually last at least 15 minutes and not more than 60 minutes per candidate.

Major details and results of the oral examination shall be recorded in the minutes. The result of the examination shall be announced to the students after the oral examination.

Students wishing to undergo the same examination in a later semester shall be admitted to oral examinations as an audience depending on spatial conditions and provided that the student to be examined has agreed. This admission shall not include the consultation of examiners and announcement of the examination results.

(7) For examinations of another type (Article 4, par. 2, No. 3), appropriate deadlines and submission dates shall be specified. It is to be ensured by the way of formulating the task and by adequate documentation that the examination result can be credited to the student. Major details and results of such a control of success shall be recorded in the minutes.

During oral examinations of another type, an associate shall be present in addition to the examiner, who shall also sign the minutes together with the examiner.

Theses or papers to be written within the framework of an examination of another type shall be provided with the following declaration: “Ich versichere wahrheitsgemäß, die Arbeit selbstständig angefertigt, alle benutzten Hilfsmittel vollständig und genau angegeben und alles kenntlich gemacht zu haben, was aus Arbeiten anderer unverändert oder mit Abänderungen entnommen wurde.” (I hereby declare that the present thesis/paper is original work written by me alone and that I have indicated completely and precisely all aids used as well as all citations, whether changed or unchanged, of other theses and publications). This declaration shall also be made in English in an equivalent form. If the thesis/paper does not contain both declarations, it shall not be accepted. Major details and results of such a control of success shall be recorded in the minutes.

**Article 6a – Controls of Success by a Multiple Choice Procedure**

It is outlined in the module manual whether and to what an extent controls of success may be made by a multiple choice test.

**Article 6b – Computer-based Controls of Success**

(1) Controls of success may be made with the help of computers. The answer or solution of the student is transmitted electronically and, if possible, evaluated automatically. The examination contents are set up by an examiner.

(2) Prior to the computer-based control of success, the examiner shall ensure that the electronic data can be identified unambiguously and allocated unmistakably and
permanently to the students. Problem-free execution of a computer-based control of
success shall be ensured by appropriate technical support. In particular, the control
of success is to be performed in the presence of a competent person. All examination
exercises shall be available for the examination during the complete examination
duration.

(3) As for the rest, Articles 6 and 6a shall apply to the execution of computer-based
controls of success.

Article 7 - Evaluation of Study Achievements and Examinations
(1) The result of an examination shall be specified by the examiners in the form of a
grade.

(2) The following grades shall be used:

- “sehr gut” (very good) for an outstanding performance;
- “gut” (good) for a performance that is far above the average;
- “befriedigend” (satisfactory) for a performance meeting average requirements;
- “ausreichend” (sufficient) for a performance that is still acceptable in spite of its deficiencies;
- “nicht ausreichend” (failed) for a performance that is no longer acceptable due to major deficiencies.

For the differentiated evaluation of individual examinations, the following grades may
be applied exclusively:

1.0, 1.3 sehr gut (very good),
1.7, 2.0, 2.3 gut (good),
2.7, 3.0, 3.3 befriedigend (satisfactory),
3.7, 4.0 ausreichend (sufficient),
5.0 nicht ausreichend (failed).

(3) Study achievements shall be rated “bestanden” (passed) or “nicht bestanden”
(failed).

(4) When determining the weighed means of module grades, subject grades, and
total grade, only the first decimal place shall be considered. All following decimal
places shall be deleted without rounding.

(5) Every module and every control of success may only be credited once in the
same program.

(6) An examination is passed, if the grade is at least “ausreichend” (4.0, sufficient).

(7) A module examination is passed, if all controls of success required have been
passed. The module examination procedure and determination of the module grade
shall be outlined in the module manual. If the module manual does not contain any
regulation regarding the determination of the module grade, the latter shall be
calculated from the grade average weighed depending on the credits of the partial modules. The differentiated grades (par. 2) shall be used as initial data for the calculation of the module grades.

(8) The results of the controls of success as well as the credits acquired shall be administrated by the Studierendenservice (Students Service) of KIT.

(9) The grades of the modules of a subject shall be considered proportionally to the credits assigned to the modules when calculating the subject grade.

(10) The total grade of the master’s examination, the subject grades, and module grades are:
- Better than or equal to 1.5 = “sehr gut” (very good),
- from 1.6 to 2.5 = “gut” (good),
- from 2.6 to 3.5 = “befriedigend” (satisfactory),
- from 3.6 to 4.0 = “ausreichend” (sufficient).

Article 8 – Repetition of Controls of Success, Final Failure

(1) Students may repeat once a written examination that has not been passed (Art. 4, par. 2, No. 1). In case a repeated written examination is evaluated with a grade of “nicht ausreichend” (5.0, failed), an oral re-examination shall take place soon after the date of the failed examination. In this case, the grade of this examination may not be better than “ausreichend” (4.0, sufficient).

(2) Students may repeat once an oral examination that has not been passed (Art. 4, par. 2, No. 2).

(3) Repeated examinations according to paragraphs 1 and 2 shall correspond to the first examination in terms of contents, scope, and type (oral or written). At request, exceptions may be approved of by the responsible examination board.

(4) Examinations of another type (Art. 4, par. 2, No. 3) may be repeated once.

(5) Study achievements may be repeated several times.

(6) The examination is finally failed, if the oral re-examination according to par. 1 is evaluated with “nicht ausreichend” (5.0, failed). In addition, the examination is finally failed, if the oral examination in the sense of par. 2 or the examination of another type according to par. 4 was evaluated twice with the grade of “nicht bestanden” (failed).

(7) The module is finally failed, if an examination required for passing finally is not passed.

(8) A second repetition of the same examination according to Article 4, par. 2 shall be possible in exceptional cases only upon application by the student (“Antrag auf Zweitwiederholung”). This application for a second repetition of an examination shall
be submitted in writing by the student to the examination board not later than two months upon the announcement of the grade.

The examination board shall decide on the first application of the student for a second repetition, if the application is approved of. If the examination board dismisses the application, a member of the Presidential Committee shall decide. Upon comment of the examination board, a member of the Presidential Committee shall decide on further applications for a second repetition. If the application is approved of, the second repetition shall take place on the next but one examination date at the latest. Paragraph 1, clauses 2 and 3 shall apply accordingly.

(9) Repetition of a passed examination shall not be permitted.

(10) In case a master’s thesis has been granted the grade “nicht ausreichend” (5.0, failed), it can be repeated once. A second repetition of the master’s thesis shall be excluded.

Article 9 – Loss of the Entitlement to an Examination
In case a student finally fails to pass a study achievement or examination required according to the present study and examination regulations or if a re-examination according to Article 8, par. 6 is not passed in due time or if the master’s examination, including potential repetitions, is not passed completely until the end of the examination period of the 7th semester, the entitlement to take an examination in the program of Optics and Photonics shall expire, unless the student is not responsible for exceeding the deadline. The decision on extending the deadline and on exceptions to the deadline regulation shall be made by the examination board taking into account the activities listed in Article 32, par. 6, LHG upon application by the student. The application shall be made in writing usually up to six weeks prior to the expiry of the deadline.

Article 10 – Deregistration, Absence, Withdrawal
(1) Students can revoke their registration for written examinations until distribution of the examination tasks without having to indicate any reasons (deregistration). Deregistration can be made online on the students portal (Studierendenportal) until 12.00 p.m. on the day before the examination or in case of justified exceptions with the Students Service (Studierendenservice) during office hours. If the deregistration is announced to the examiner, the latter shall take care of the deregistration being booked in the campus management system.

(2) In case of oral examinations, deregistration shall be declared to the examiner three working days prior to the date of examination at the latest. Withdrawal from an oral examination less than three working days prior to the date of examination shall only be permitted under the conditions of par. 5. Withdrawal from oral re-examinations in the sense of Article 9, par. 1 shall be possible under the conditions outlined in par. 5 only.
(3) Deregistration from examinations of another type as well as from study achievements is described in the module manual.

(4) A control of success shall be deemed to have been “nicht ausreichend” (5.0, failed), if the students fail to be present at the examination without a good reason or if they withdraw from the control of success after its start without a good reason. The same shall apply, if the master’s thesis has not been submitted within the period envisaged, unless the student is not responsible for having exceeded the deadline.

(5) The reason given for withdrawal after the start of the control of success or absence shall be notified immediately, credibly, and in writing to the examination board. In case of an illness of the student or of a child maintained by the student alone or of a relative in need of care, submission of a medical certificate may be required.

Article 11 – Deception, Breach of Regulations

(1) In case students try to influence the result of their control of success by deception or the use of impermissible aids, this control of success shall be deemed to have been “nicht ausreichend” (failed, 5.0).

(2) Students disturbing the proper execution of a control of success may be excluded from the continuation of the control of success by the examiner or the supervisor. In this case, this control of success shall be deemed to have been “nicht ausreichend” (failed, 5.0). In serious cases, the examination board may exclude these students from further controls of success.

(3) Details relating to honesty during examinations and traineeships are outlined in the General Statutes of KIT, as amended.

Article 12 - Maternity Protection, Parental Leave, Assumption of Family Obligations

(1) At the student’s request, the maternity protection periods as defined by the Act for the Protection of the Working Mother (Mutterschutzgesetz - MuSchG), as amended, shall be considered accordingly. The required evidence shall be enclosed with this request. The maternity protection periods suspend any deadline according to the present examination regulations. The duration of maternity protection shall not be included in the deadline given.

(2) At request, the deadlines of parental leave shall be considered according to the valid legislation (Bundeselterngeld- und Elternzeitgesetz - BEGG). Four weeks prior to the desired start of the parental leave period at the latest, the student shall inform the examination board in writing about the desired time of start of parental leave. The required evidence shall be enclosed. The examination board shall then check whether the legal prerequisites would justify an employee’s claim for parental leave and inform the student immediately of the result and the new times of examination. The period of work on the master’s thesis may not be interrupted by parental leave.
In this case, the thesis shall be deemed to have not been assigned. Upon expiry of the parental leave period, the student shall receive a new subject that is to be dealt with within the period specified in Article 14.

(3) At request, the examination board shall decide on the flexible handling of examination deadlines according to the provisions of the Law of Baden-Württemberg on Universities and Colleges, if students have to assume family obligations. Paragraph 2, clauses 4 to 6 shall apply accordingly.

**Article 13 – Students with a Handicap or Chronic Illness**

(1) When executing and organizing studies and examinations, the interests of students with handicaps or chronic illnesses shall be taken into account. In particular, students with a handicap or chronic illness shall be granted preferred access to courses with a limited number of participants and the order of passing certain courses shall be adapted to their needs. According to the Federal Equality Act (Bundesgleichstellungsgesetz, BGG) and Volume 9 of the Social Insurance Code (Sozialgesetzbuch 9. Buch, SGB IX), students are handicapped, if their bodily function, mental capacity, or emotional health with high probability deviates from the condition typical of a person of that age for a period longer than six months and their participation in social life is therefore impaired. At the request of the student, the examination board shall decide on whether conditions according to clauses 2 and 3 apply. The student shall furnish the corresponding evidence.

(2) In case students furnish evidence of a handicap or chronic illness and if, as a result, they are not able to pass controls of success completely or partly in the time or form required, the examination board may permit them to pass the controls of success within another period of time or in another form. In particular, handicapped students shall be permitted to use the required aids.

(3) In case students furnish evidence of a handicap or a chronic illness and if, as a result, they are not able to regularly attend the courses or to reach the study and examination achievements required according to Article 19, the examination board may permit, at their request, to have them pass individual study and examination achievements upon expiry of the deadlines envisaged in the present Study and Examination Regulations.

**Article 14 - Master’s Thesis Module**

(1) Students who have successfully passed all module examinations and internships required except for two module examinations at the maximum shall be accepted for the master’s thesis module. Prior to the registration of the master’s thesis module, the optics and photonics labs, the seminar course, and the internship have to be passed. The application for admission to the master’s thesis shall be submitted three months after the last module examination at the latest. At request of the student, the examination board shall decide on exceptions.
(1a) 30 credits shall be assigned to the master’s thesis module. It shall consist of the master’s thesis and a presentation. The presentation shall be made within six months upon registration for the master’s thesis.

(2) The master’s thesis can be assigned by university teachers and executive scientists according to Article 14, par. 3, clause 1 KITG. In addition, the examination board can authorize further examiners to assign the subject according to Article 17, pars. 2 to 4. The students shall be given the possibility to propose the subject. In case the master’s thesis shall be written outside of the four KIT departments involved according to Article 1, clause 2, the approval of the examination board shall be required. The master’s thesis may also be permitted in the form of group work, provided that the contributions of the individual students that are to be evaluated as examination achievements can be distinguished clearly based on objective criteria and the requirements outlined in par. 4 are met. At the student’s request, the chairperson of the examination board, by way of exception, shall take care of the student receiving a subject for the master’s thesis within four weeks upon application. In this case, the subject is assigned by the chairperson of the examination board.

(3) The subject, task, and scope of the master’s thesis shall be limited by the examiner, such that the master’s thesis can be handled with the expenditure outlined in par. 4.

(4) The master’s thesis shall demonstrate that the students are able to deal with a problem in the subject area of optics & photonics in an independent manner and within the given period of time using scientific methods. 30 credits shall be assigned to the master’s thesis. The maximum duration of work on the thesis shall amount to six months. The subject and task shall be adapted to the scope envisaged. The master’s thesis shall be written in the English language.

(5) When submitting the master’s thesis, the students shall assure in writing that the thesis is original work by them alone and that they have used no sources and aids other than those indicated and that they have adequately marked all citations either literally or textually and observed the KIT Statutes for Upholding Good Scientific Practice, as amended. If the thesis does not contain this declaration, it shall not be accepted. The declaration may be as follows: “Ich versichere wahrheitsgemäß, die Arbeit selbstständig verfasst, alle benutzten Hilfsmittel vollständig und genau angegeben und alles kenntlich gemacht zu haben, was aus Arbeiten anderer unverändert oder mit Abänderungen entnommen wurde sowie die Satzung des KIT zur Sicherung guter wissenschaftlicher Praxis in der jeweils gültigen Fassung beachtet zu haben” (I herewith declare that the present thesis is original work written by me alone, that I have indicated completely and precisely all aids used as well as all citations, whether changed or unchanged, of other theses and publications, and that I have observed the KIT Statutes for Upholding Good Scientific Practice, as amended). This declaration shall also be made in English in an equivalent form. If the declaration is not true, the master’s thesis shall be given the grade “nicht ausreichend” (5.0, failed).
(6) The time of assignment of the subject of the master’s thesis shall be documented by the assigning examiner and the student as well as in the files of the examination board. The time of submission of the master’s thesis shall be documented by the examiner/s with the examination board. The student shall be allowed to return the subject of the master’s thesis once only within the first month of the period of work on the thesis. At the justified request of the student, the examination board may extend this time of work on the thesis according to par. 4 by three months at the maximum. If the master’s thesis is not submitted in time, it shall be deemed to have been “nicht ausreichend” (5.0, failed), unless the candidate is not responsible for this delay.

(7) The master’s thesis shall be evaluated by at least one university teacher or one executive scientist according to Article 14, par. 3, No. 1 KITG and another additional examiner. As a rule, one of the examiners is the person who has assigned the subject according to par. 2. In case of a deviating evaluation of these two persons, the examination board shall decide on the grade of the master’s thesis. It may also appoint another reviewer. The evaluation shall be made within a period of eight weeks upon submission of the master’s thesis.

Article 14a - Internship

(1) In the course of the master’s program, an internship of eight weeks’ duration shall be passed. This internship shall be suited to give the students an idea of professional practice in the field of optics & photonics. 12 credits shall be assigned to the internship, inclusive of the final report and presentation.

(2) In their own responsibility, the students shall contact appropriate private or public institutions for passing the internship. The candidate shall be supervised by an examiner according to Art. 17, par. 2 in addition to the external supervisor. As a rule, the internship shall not be completed at KIT and in case of multiple degrees (e.g. under ERASMUS MUNDUS programs), it also shall not be completed at one of the partner institutions. Details are outlined in the module manual.

Article 15 - Additional Achievements

(1) The students shall be free to acquire further credits (additional achievements) in the amount of 30 credits at the maximum in the courses offered by KIT. Articles 3 and 4 of the Examination Regulations shall remain unaffected. These additional achievements shall not be considered when calculating the total and module grades. The credits not considered when determining the module grade shall be included automatically in the transcript of records and marked as additional achievements. At the student’s request, additional achievements shall be included in the master’s certificate and marked as additional achievements. Additional achievements shall be listed with the grades according to Article 7.

(2) When signing up for an examination in a module, the students shall declare it as an additional achievement already. At the students’ request, classification of the module can be changed later on.
Article 15a – Key Competencies
Apart from the scientific modules, key competencies modules of at least six credits shall be part of the KIT’s master’s program of Optics & Photonics. Key competencies may be a module of their own or part of another scientific module.

Article 16 - Examination Board
(1) For the master’s program of Optics & Photonics, an examination board shall be formed. It shall consist of six members entitled to vote: Four university teachers / executive scientists according to Article 14, par. 3, No. 1 KITG / assistant professors of the four KIT departments according to Art. 1, clause 2, two representatives of the academic staff according to Art. 52 LHG / scientific staff members according to Art. 14, par. 3, No. 2 KITG, and one representative of the students with an advisory vote. The term of office of the non-student members shall be two years, the term of office of the student member shall be one year. Every KIT department involved according to Art. 1, clause 2 shall be represented by a member entitled to vote.

(2) The chairperson, his/her deputy, the other members of the examination board, and their deputies shall be appointed by the respective KIT department councils, the academic staff members according to Art. 52 LHG, the members of the group of scientists according to Art. 14, par. 3, No. 2 KITG, and the representative of the students according to the proposal made by the members of the respective group. Reappointment shall be possible. The chairperson and his/her deputy shall be university teachers or executive scientists according to Art. 14, par. 3, No. 1 KITG. The chair shall alternate among the KIT departments every two years. The chairperson of the examination board shall be responsible for current transactions and supported by the respective examination office.

(3) The examination board shall be responsible for the observation and implementation of the present Study and Examination Regulations in the practice of the departments involved according to Art. 1, clause 2. It shall decide on matters of the examinations and on the recognition of study periods and study and examination achievements and make the decision according to Art. 18, par. 1, clause 1. It shall regularly report to the KIT departments involved according to Art. 1, clause 2 about the development of examination and study periods as well as about the times of work on the master’s theses and the distribution of module and total grades. It shall also propose reforms of the Study and Examination Regulations and module descriptions. The examination board shall decide with the majority of votes. In the event of a tie, the chairperson of the examination board shall have the casting vote.

(4) The examination board may assign the execution of its tasks in all normal cases to the chairperson of the examination board. In urgent matters, the execution of which cannot wait until the next meeting of the examination board, the chairperson of the examination board shall decide.

(5) The members of the examination board shall have the right to participate in examinations. The members of the examination board, the examiners, and the associates shall be under the obligation of discretion. If they do not work in the public
service sector, they shall be obliged to secrecy by the chairperson of the examination board.

(6) In matters of the examination board, which are related to an examination to be passed at another KIT department, a competent person authorized to examine and to be appointed by the respective KIT department shall be consulted at the request of a member of the examination board.

(7) The student shall be informed in writing about incriminating decisions by the examination board. These decisions shall be justified and provided with an information on legal remedies available. Prior to the decision, the student shall be given the opportunity to be heard. Objections against decisions made by the examination board shall be addressed to the Presidential Committee of KIT in writing or for record within one month upon receipt of the decision.

Article 17 - Examiners and Associates
(1) The examination board shall appoint the examiners. It may delegate appointment to its chairperson.

(2) Examiners shall be university teachers and executive scientists according to Art. 14, par. 3, No. 1 KITG, members of the respective KIT departments having post-doctoral lecture qualification as well as academic staff members according to Art. 52 LHG working at the respective KIT departments, who are authorized to examine students. In addition, scientific staff members according to Art. 14, par. 3, No. 2 KITG can be authorized to examine students. For appointment, persons shall have the scientific qualification corresponding to the examination subject at least.

(3) If courses are offered by persons other than those mentioned under par. 2, these shall be appointed examiners, if one of the KIT departments involved according to Art. 1, cl. 2 has granted them the authorization to examine and they can furnish evidence of the qualification required according to par. 2, cl. 2.

(4) In case master’s theses are assigned or supervised by persons other than those mentioned in par. 2, these persons may be appointed examiners by way of exception, if one of the KIT departments involved according to Art. 1, cl. 2 has granted them the authorization to examine and they can furnish evidence of the qualification needed according to par. 2, cl. 2.

(5) Associates shall be appointed by the examiners. Only persons having acquired an academic degree in a master’s program of the KIT departments involved according to Art. 1, cl. 2 or an equivalent academic degree may be appointed associate.
Article 18 - Recognition of Study and Examination Achievements, Study Periods

(1) Study and examination achievements made as well as study periods passed in study programs at state or state-recognized universities and cooperative state universities of the Federal Republic of Germany or at foreign state or state-recognized universities shall be recognized at the request of the students, if the competencies acquired do not differ considerably from the achievements or degrees to be replaced. No schematic comparison, but an overall analysis shall be made. As regards the scope of a study or examination achievement to be recognized, the principles of the ECTS shall be applied.

(2) Students shall submit the documents required for recognition. Students newly enrolled in the master’s program of Optics & Photonics shall submit the application, together with the documents required for recognition, within one semester upon enrollment. In case of documents that are not available in the German or English language, an officially certified translation may be requested. The examination board shall bear the burden of proving that the application does not meet the recognition requirements.

(3) If achievements made not at the KIT are recognized, they shall be indicated to be “anerkannt” (recognized) in the transcript. If grades exist, the grades shall be taken over in case of comparable grade scales and considered when calculating the module grades and total grade. In case of incomparable grade systems, the grades can be converted. If no grades exist, the note “bestanden” (passed) shall be made.

(4) When recognizing study and examination achievements made outside of the Federal Republic of Germany, the equivalence agreements adopted by the Conference of Ministers of Education and the German Rectors’ Conference as well as agreements concluded within the framework of university partnerships shall be considered.

(5) Knowledge and skills acquired outside of the university system shall be recognized, if they are equivalent in terms of contents and level to the study and examination achievements to be replaced and the institution, where the knowledge and skills were acquired, has a standardized quality assurance system. Recognition may be refused partly, if more than 50% of the university studies are to be replaced.

(6) The examination board shall be responsible for recognition and crediting. To determine whether a considerable difference in the sense of par. 1 exists, the responsible subject representatives shall be heard. Depending on the type and scope of study and examination achievements to be recognized, the examination board shall decide on admission to a higher semester.
Article 19 - Scope and Type of the Master's Examination

(1) The master's examination shall consist of the module examinations according to paragraphs 2 and 3, the master's thesis module (Art. 14), and the internship (Art. 14a).

(2) Module examinations shall be passed in the following mandatory subjects:
1. Engineering Optics & Photonics: Modules of 8 credits;
2. Physical Optics & Photonics: Modules of 8 credits;
3. Advanced Optics & Photonics – Theory and Materials: Modules of 8 credits;
4. Advanced Optics & Photonics – Methods and Components: Modules of 10 credits;
5. Adjustment courses: Modules of 8 credits;
6. Optics & Photonics lab: Modules of 10 credits;
7. Seminar course (research topics in Optics & Photonics): Modules of 4 credits;
8. Key qualifications of at least 6 credits according to Art. 15a.

The modules to be selected and their allocation to the subjects are outlined in the module manual.

(3) In the area of specializations, module examinations of 16 credits shall be passed in one of the following subjects:
- Specialization – Photonic Materials and Devices;
- Specialization – Advanced Spectroscopy;
- Specialization – Biomedical Photonics;
- Specialization – Optical Systems;
- Specialization – Solar Energy.

The modules that can be selected in these subjects are outlined in the module manual.

Article 20 - Passing of the Master's Examination, Calculation of the Total Grade

(1) The master's examination shall be passed, if all module examinations mentioned in Art. 19 were evaluated with the grade “ausreichend” (sufficient) at least and the corresponding study achievements were made.

(2) The total grade of the master's examination shall be the mean of the grades of subjects according to Art. 19, par. 2, Nos. 1 – 4 and Art. 19, par. 3 weighed with credits and of the grade of the master's thesis module.

(3) In case students have completed the master's thesis with the grade 1.0 and the master's examination with an average of better than 1.3, the predicate “mit Auszeichnung” (with distinction) shall be granted.
Article 21 – Master’s Transcript, Master’s Certificate, Diploma Supplement, and Transcript of Records

(1) Upon evaluation of the last examination, a master’s certificate and a transcript shall be issued about the master’s examination. The master’s certificate and transcript shall be issued not later than three months upon the last examination. The master’s certificate and transcript shall be issued in the German and English languages. The master’s certificate and transcript shall bear the date of the successful passing of the last examination. They shall be handed over to the students together. The master’s certificate shall document the conferral of the academic degree of master. The master’s certificate shall be signed by the President and the dean of the KIT department, where the master’s thesis was written. This certificate shall be provided with the seal of KIT.

(2) The transcript shall list the subject and module grades, the credits assigned to the modules and subjects, and the total grade. If a differentiated evaluation of individual examination achievements was made according to Art. 7, par. 2, cl. 2, the corresponding decimal grade shall also be indicated on the transcript. Art. 7, par. 4 shall remain unaffected. The transcript shall be signed by the KIT dean of the KIT department, where the master’s thesis was written, and by the chairperson of the examination board.

(3) In addition to the transcript, the students shall be given a diploma supplement in the German and English languages, which corresponds to the requirements of the applicable ECTS Users Guide, and a transcript of records in the German and English languages.

(4) The transcript of records shall list all study and examination achievements of the student in a structured form. This shall include all subjects, subject grades, and the assigned credits, the modules assigned to the subject together with the module grades and the assigned credits as well as controls of success assigned to the modules together with the grades and assigned credits. Par. 2, cl. 2 shall apply accordingly. The transcript of records shall clearly reflect the assignment of courses to the individual modules. Recognized study and examination achievements shall be included in the transcript of records. All additional achievements shall be listed in the transcript of records.

(5) The master’s certificate, master’s transcript, and the diploma supplement, including the transcript of records, shall be issued by the Students Service (Studierendenservice) of KIT.

III. Final Provisions

Article 22 - Certificate of Examination Achievements

(1) In case students have ultimately failed in the master’s examination, they shall be given at request and against submission of the exmatriculation certificate a written
Article 23 - Deprivation of the Master’s Degree

(1) If students have been guilty of deception during an examination and if this fact becomes known upon the hand-over of the transcript only, the grades for the module examinations, during which the students were guilty of deception, may be corrected. This module examination may be declared to have been “nicht ausreichend” (5.0, failed) and the master’s examination to have been “nicht bestanden” (failed).

(2) If the conditions for admission to an examination were not fulfilled without the student wanting to deceive and if this fact becomes known upon the hand-over of the transcript only, this default shall be remedied by the passing of the examination. If the student intentionally and wrongly obtained admission to the examination, the module examination may be declared to have been “nicht ausreichend” (5.0, failed) and the master’s examination to have been “nicht bestanden” (failed).

(3) Prior to a decision of the examination board, the student shall be given the opportunity to be heard.

(4) The incorrect transcript shall be confiscated and, if applicable, a new transcript shall be issued. Together with the incorrect transcript, the master’s certificate shall be confiscated, if the master’s examination was declared to have been “nicht bestanden” (failed) due to a deception.

(5) A decision pursuant to par. 1 and par. 2, cl. 2 shall be excluded after a period of five years upon the date of issue of the transcript.

(6) Deprivation of the academic degree shall be subject to Art. 36, par. 7 LHG.

Article 24 - Inspection of Examination Files

(1) Upon completion of the master’s examination, the students shall be granted the right to inspect their master’s thesis, the related opinions, and minutes of the examination within one year at request.

(2) For inspection of written module examinations, written module partial examinations, and minutes of examinations, a deadline of one month upon announcement of the examination result shall apply.

(3) The examiner shall determine the place and time of inspection.

(4) Examination documents shall be kept for at least five years.
Article 25 - Entry into Force, Transition Regulations

(1) The present Study and Examination Regulations shall enter into force on October 01, 2015.

(2) At the same time, the Study and Examination Regulations of KIT about the Master’s Program of Optics & Photonics of September 27, 2012 (official announcement of KIT No. 52 of September 27, 2012), last amended by the statutes of March 27, 2014 (official announcement of KIT No. 19 of March 28, 2014) shall cease to be in force.

(3) Students, who have started their studies at Karlsruhe Institute of Technology (KIT) based on the Study and Examination Regulations of Karlsruhe Institute of Technology (KIT) about the Master’s Program of Optics & Photonics of September 27, 2012 (official announcement of Karlsruhe Institute of Technology (KIT) No. 52 of September 27, 2012), last amended by the statutes of March 27, 2014 (official announcement of KIT No. 19 of March 28, 2014), may apply for examination according to those regulations on September 30, 2018 for the last time.

(4) Students, who have started their studies at KIT based on the Study and Examination Regulations about the Master’s Program of Optics & Photonics of September 27, 2012 (official announcement of KIT No. 52 of September 27, 2012), last amended by the statutes of March 27, 2014 (official announcement of KIT No. 19 of March 28, 2014), may continue their studies according to those study and examination regulations at request.

Karlsruhe, August 04, 2015

Professor Dr.-Ing. Holger Hanselka
(President)
<table>
<thead>
<tr>
<th>German Term</th>
<th>English Translation</th>
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<tr>
<td>Studien- und Prüfungsordnung</td>
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<td>Modulhandbuch</td>
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Erklärung in der Masterarbeit (deutsch und englisch):

"Ich versichere wahrheitsgemäß, die Arbeit selbstständig verfasst, alle benutzten Hilfsmittel vollständig und genau angegeben und alles kenntlich gemacht zu haben, was aus Arbeiten anderer unverändert oder mit Abänderungen entnommen wurde sowie die Satzung des KIT zur Sicherung guter wissenschaftlicher Praxis in der jeweils gültigen Fassung beachtet zu haben" (I herewith declare that the present thesis is original work written by me alone, that I have indicated completely and precisely all aids used as well as all citations, whether changed or unchanged, of other theses and publications, and that I have observed the KIT Statutes for Upholding Good Scientific Practice, as amended).
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