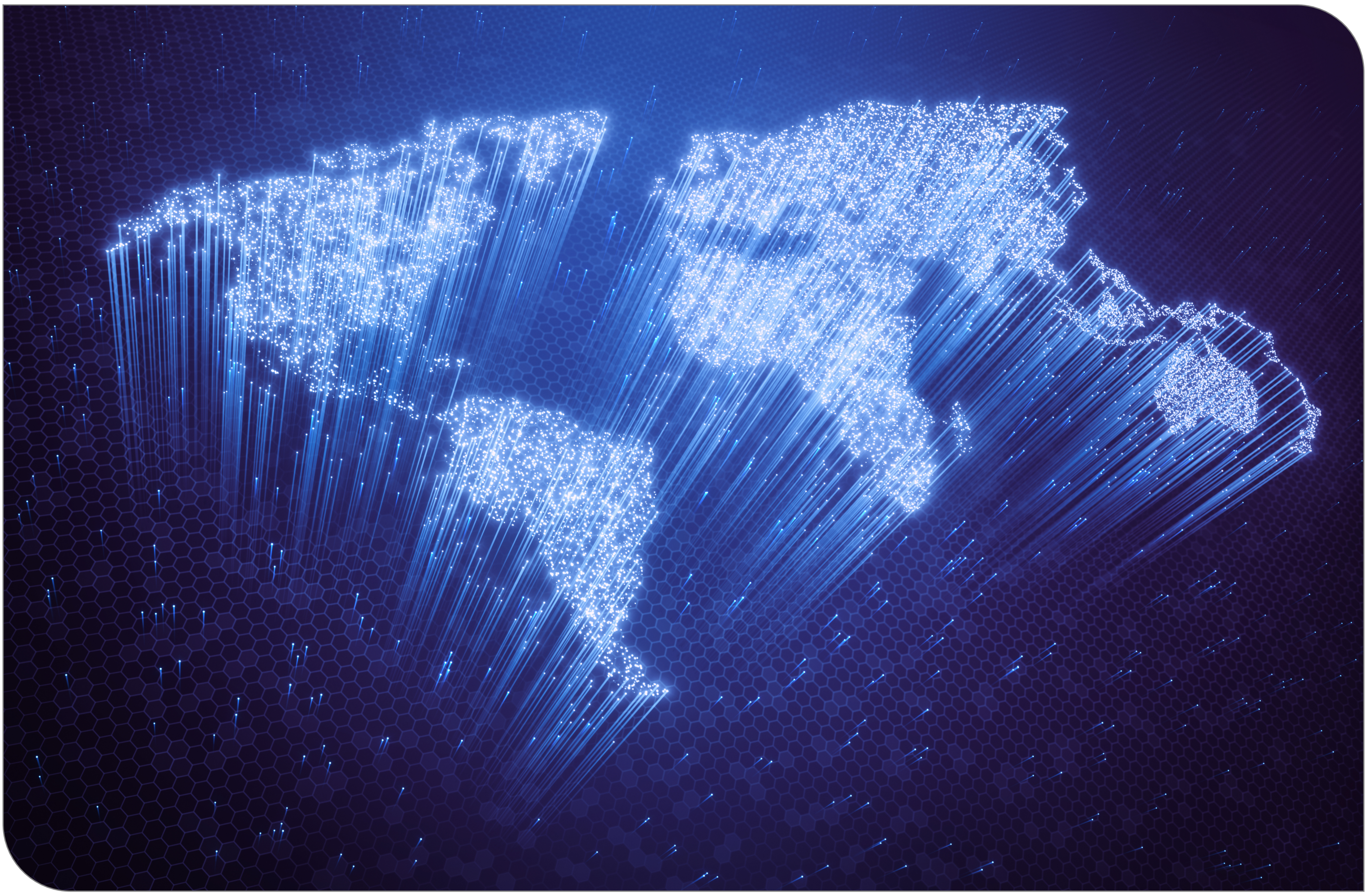
# Module Handbook
# Optics and Photonics Master 2015 (Master of Science (M.Sc.))

SPO 2015

Winter term 2024/25

Date: 16/10/2024

KIT DEPARTMENT OF ELECTRICAL ENGINEERING AND INFORMATION TECHNOLOGY



# Table Of Contents

# 1 Field of study structure

| Mandatory | |
|---|---|
| Master's Thesis | 30 CR |
| Internship<br>*This field will not influence the calculated grade of its parent.* | 12 CR |
| Engineering Optics & Photonics | 8 CR |
| Physical Optics & Photonics | 8 CR |
| Advanced Optics & Photonics – Theory and Materials | 8 CR |
| Advanced Optics & Photonics – Methods and Components | 10 CR |
| Adjustment Courses<br>*First usage possible from May 24, 2022.*<br>*This field will not influence the calculated grade of its parent.* | 8 CR |
| Optics & Photonics Lab<br>*This field will not influence the calculated grade of its parent.* | 10 CR |
| Seminar Course (Research Topics in Optics & Photonics)<br>*This field will not influence the calculated grade of its parent.* | 4 CR |
| Interdisciplinary Qualifications<br>*This field will not influence the calculated grade of its parent.* | 6 CR |
| Specialization | 16 CR |
| **Voluntary** | |
| Additional Achievements<br>*This field will not influence the calculated grade of its parent.* | |

## 1.1 Master's Thesis

**Credits**
30

| Mandatory | | |
|---|---|---|
| M-ETIT-102362 | Module Master's Thesis | 30 CR |

## 1.2 Internship

**Credits**
12

| Mandatory | | |
|---|---|---|
| M-ETIT-102360 | Internship | 12 CR |

## 1.3 Engineering Optics & Photonics

**Credits**
8

| Engineering Optics & Photonics (Election: 8 credits) | | |
|---|---|---|
| M-ETIT-100386 | Electromagnetics and Numerical Calculation of Fields | 4 CR |
| M-ETIT-100456 | Optical Engineering | 4 CR |

## 1.4 Physical Optics & Photonics

**Credits**
8

| Physical Optics & Photonics (Election: 8 credits) | | |
|---|---|---|
| M-PHYS-101927 | Fundamentals of Optics and Photonics | 8 CR |

## 1.5 Advanced Optics & Photonics – Theory and Materials

**Credits**
8

| **Mandatory** | | |
|---|---|---|
| M-PHYS-102280 | Theoretical Optics | 4 CR |
| M-ETIT-100430 | Nonlinear Optics | 4 CR |

## 1.6 Advanced Optics & Photonics – Methods and Components

**Credits**
10

| **Mandatory** | | |
|---|---|---|
| M-ETIT-100509 | Optoelectronic Components | 4 CR |
| M-ETIT-101919 | Fabrication and Characterisation of Optoelectronic Devices | 3 CR |
| M-CHEMBIO-101900 | Spectroscopic Methods | 3 CR |

## 1.7 Adjustment Courses

**Credits**
8

**Note regarding usage**
First usage possible from May 24, 2022.

| **Mandatory** | | |
|---|---|---|
| M-CHEMBIO-101903 | Basic Molecular Cell Biology | 2 CR |
| **Modern Physics / Measurement and Control Systems (Election: 1 item)** | | |
| M-PHYS-101931 | Modern Physics | 6 CR |
| M-MACH-101921 | Measurement and Control Systems | 6 CR |

## 1.8 Optics & Photonics Lab

**Credits**
10

| **Mandatory** | | |
|---|---|---|
| M-PHYS-102189 | Optics and Photonics Lab | 10 CR |

## 1.9 Seminar Course (Research Topics in Optics & Photonics)

**Credits**
4

| **Mandatory** | | |
|---|---|---|
| M-PHYS-102195 | Seminar Course | 4 CR |

## 1.10 Interdisciplinary Qualifications

**Credits**
6

| **Interdisciplinary Qualification (Election: at least 6 credits)** | | |
|---|---|---|
| M-ETIT-101834 | Business Innovation in Optics and Photonics | 4 CR |
| M-ETIT-105665 | Introduction to the Scientific Method (Seminar, English)<br>*First usage possible from Apr 01, 2021.* | 1 CR |

## 1.11 Specialization

**Credits**
16

| Specialization (Election: 1 item) | |
|---|---|
| Specialization - Photonic Materials and Devices | 16 CR |
| Specialization - Biomedical Photonics | 16 CR |
| Specialization - Optical Systems | 16 CR |
| Specialization - Solar Energy | 16 CR |
| Specialization - Quantum Optics & Spectroscopy<br>*First usage possible from Oct 01, 2019.* | 16 CR |

### 1.11.1 Specialization - Photonic Materials and Devices

**Part of: Specialization**

**Credits**
16

| Specialization - Photonic Materials and Devices (Election: at least 16 credits) | | |
|---|---|---|
| M-ETIT-100435 | Laser Physics | 4 CR |
| M-ETIT-100436 | Optical Transmitters and Receivers | 6 CR |
| M-ETIT-100506 | Optical Waveguides and Fibers | 4 CR |
| M-ETIT-100524 | Solar Energy | 6 CR |
| M-ETIT-100566 | Field Propagation and Coherence | 4 CR |
| M-PHYS-102194 | Research Project | 4 CR |
| M-PHYS-102408 | Solid-State Optics | 6 CR |
| M-MACH-101920 | X-Ray Optics | 3 CR |
| M-ETIT-100475 | Plastic Electronics / Polymerelectronics | 3 CR |
| M-CHEMBIO-101901 | Advanced Inorganic Materials | 3 CR |
| M-PHYS-102146 | Nano-Optics | 6 CR |
| M-PHYS-103093 | Quantum Optics | 4 CR |
| M-PHYS-103089 | Computational Photonics, without ext. Exercises | 4 CR |
| M-ETIT-103270 | Optical Networks and Systems | 4 CR |
| M-ETIT-103802 | Adaptive Optics<br>*First usage possible from Apr 01, 2018.* | 3 CR |
| M-PHYS-102295 | Theoretical Nanooptics<br>*First usage possible from Oct 01, 2019.* | 6 CR |
| M-ETIT-105914 | Photonic Integrated Circuit Design and Applications<br>*First usage possible from Apr 01, 2022.* | 6 CR |

### 1.11.2 Specialization - Biomedical Photonics

**Part of: Specialization**

**Credits**
16

| Compulsory Modules (Election: at least 5 credits) | | |
|---|---|---|
| M-CHEMBIO-101904 | Advanced Molecular Cell Biology | 5 CR |
| **Compulsory Elective Modules (Election: at least 11 credits)** | | |
| M-ETIT-100435 | Laser Physics | 4 CR |
| M-PHYS-102146 | Nano-Optics | 6 CR |
| M-PHYS-102194 | Research Project | 4 CR |
| M-CHEMBIO-101907 | Organic Photochemistry | 3 CR |
| M-CHEMBIO-101905 | Imaging Techniques in Light Microscopy | 3 CR |
| M-CHEMBIO-101906 | Optics and Vision in Biology | 4 CR |
| M-ETIT-103252 | Optical Systems in Medicine and Life Science | 3 CR |
| M-ETIT-103802 | Adaptive Optics | 3 CR |

**Modelled Conditions**
The following conditions have to be fulfilled:

1. The field Specialization - Biomedical Photonics - Erasmus must not have been started.

## 1.11.3 Specialization - Optical Systems

**Part of: Specialization**

**Credits** 16

| Specialization - Optical Systems (Election: at least 16 credits) | | |
|---|---|---|
| M-ETIT-100434 | Laser Metrology | 3 CR |
| M-ETIT-100435 | Laser Physics | 4 CR |
| M-ETIT-100436 | Optical Transmitters and Receivers | 6 CR |
| M-ETIT-100506 | Optical Waveguides and Fibers | 4 CR |
| M-ETIT-100512 | Light and Display Engineering | 4 CR |
| M-ETIT-100537 | Systems and Software Engineering | 4 CR |
| M-ETIT-100566 | Field Propagation and Coherence | 4 CR |
| M-ETIT-100577 | Lighting Design - Theory and Applications | 3 CR |
| M-PHYS-102194 | Research Project | 4 CR |
| M-MACH-101923 | Machine Vision | 6 CR |
| M-ETIT-100475 | Plastic Electronics / Polymerelectronics | 3 CR |
| M-PHYS-103093 | Quantum Optics | 4 CR |
| M-PHYS-103089 | Computational Photonics, without ext. Exercises | 4 CR |
| M-ETIT-103252 | Optical Systems in Medicine and Life Science | 3 CR |
| M-MACH-102693 | Automotive Vision | 4 CR |
| M-ETIT-103270 | Optical Networks and Systems | 4 CR |
| M-ETIT-103450 | Digital Signal Processing in Optical Communications – with Practical Exercises<br>*First usage possible from Apr 01, 2018.* | 6 CR |
| M-MACH-101920 | X-Ray Optics | 3 CR |
| M-PHYS-102295 | Theoretical Nanooptics<br>*First usage possible from Oct 01, 2019.* | 6 CR |
| M-ETIT-105461 | Introduction to Automotive and Industrial Lidar Technology<br>*First usage possible from Oct 01, 2020.* | 3 CR |
| M-ETIT-105914 | Photonic Integrated Circuit Design and Applications<br>*First usage possible from Apr 01, 2022.* | 6 CR |
| M-ETIT-103802 | Adaptive Optics | 3 CR |

## 1.11.4 Specialization - Solar Energy

**Part of: Specialization**

**Credits** 16

| Compulsory Modules (Election: at least 6 credits) | | |
|---|---|---|
| M-ETIT-100524 | Solar Energy | 6 CR |
| **Compulsory Elective Modules (Election: at least 10 credits)** | | |
| M-ETIT-101917 | Electric Power Generation and Power Grid | 3 CR |
| M-PHYS-102194 | Research Project | 4 CR |
| M-PHYS-102408 | Solid-State Optics | 6 CR |
| M-ETIT-100475 | Plastic Electronics / Polymerelectronics | 3 CR |
| M-PHYS-102146 | Nano-Optics | 6 CR |
| M-PHYS-103089 | Computational Photonics, without ext. Exercises | 4 CR |
| M-MACH-101924 | Solar Thermal Energy Systems | 3 CR |
| M-PHYS-102295 | Theoretical Nanooptics<br>*First usage possible from Oct 01, 2019.* | 6 CR |

**Modelled Conditions**

The following conditions have to be fulfilled:

1. The field Specialization - Solar Energy - Erasmus must not have been started.

## 1.11.5 Specialization - Quantum Optics & Spectroscopy

**Part of: Specialization**

**Credits**
16

**Note regarding usage**
First usage possible from Oct 01, 2019.

| Specialization - Quantum Optics & Spectroscopy (Election: at least 16 credits) | | |
|---|---|---|
| M-ETIT-100435 | Laser Physics | 4 CR |
| M-ETIT-100434 | Laser Metrology | 3 CR |
| M-PHYS-102146 | Nano-Optics | 6 CR |
| M-PHYS-102194 | Research Project | 4 CR |
| M-PHYS-102408 | Solid-State Optics | 6 CR |
| M-CHEMBIO-101901 | Advanced Inorganic Materials | 3 CR |
| M-CHEMBIO-101902 | Molecular Spectroscopy | 4 CR |
| M-PHYS-103093 | Quantum Optics | 4 CR |
| M-ETIT-103802 | Adaptive Optics | 3 CR |
| M-ETIT-105914 | Photonic Integrated Circuit Design and Applications<br>*First usage possible from Apr 01, 2022.* | 6 CR |
| M-PHYS-106508 | Quantum Optics at the Nano Scale, with Exercises<br>*First usage possible from Apr 01, 2023.* | 8 CR |
| M-PHYS-106510 | Quantum Optics at the Nano Scale, without Exercises<br>*First usage possible from Apr 01, 2023.* | 6 CR |

## 1.12 Additional Achievements

| Additional Examinations (Election: at most 30 credits) | | |
|---|---|---|
| M-ETIT-102000 | Further Examinations | 30 CR |
| M-ETIT-100435 | Laser Physics | 4 CR |
| M-ETIT-100436 | Optical Transmitters and Receivers | 6 CR |
| M-ETIT-100506 | Optical Waveguides and Fibers | 4 CR |
| M-ETIT-100566 | Field Propagation and Coherence | 4 CR |
| M-PHYS-102194 | Research Project | 4 CR |
| M-PHYS-102408 | Solid-State Optics | 6 CR |
| M-MACH-101920 | X-Ray Optics | 3 CR |
| M-ETIT-100434 | Laser Metrology | 3 CR |
| M-PHYS-102146 | Nano-Optics | 6 CR |
| M-ETIT-100512 | Light and Display Engineering | 4 CR |
| M-ETIT-100537 | Systems and Software Engineering | 4 CR |
| M-ETIT-100577 | Lighting Design - Theory and Applications | 3 CR |
| M-MACH-101923 | Machine Vision | 6 CR |
| M-ETIT-100524 | Solar Energy | 6 CR |
| M-ETIT-101917 | Electric Power Generation and Power Grid | 3 CR |
| M-ETIT-100475 | Plastic Electronics / Polymerelectronics | 3 CR |
| M-CHEMBIO-101901 | Advanced Inorganic Materials | 3 CR |
| M-CHEMBIO-101902 | Molecular Spectroscopy | 4 CR |
| M-CHEMBIO-101904 | Advanced Molecular Cell Biology | 5 CR |
| M-CHEMBIO-101905 | Imaging Techniques in Light Microscopy | 3 CR |
| M-CHEMBIO-101906 | Optics and Vision in Biology | 4 CR |
| M-CHEMBIO-101907 | Organic Photochemistry | 3 CR |
| M-ETIT-103252 | Optical Systems in Medicine and Life Science | 3 CR |
| M-MACH-102693 | Automotive Vision | 4 CR |
| M-PHYS-103089 | Computational Photonics, without ext. Exercises | 4 CR |
| M-PHYS-103093 | Quantum Optics | 4 CR |
| M-ETIT-101834 | Business Innovation in Optics and Photonics | 4 CR |
| M-MACH-101924 | Solar Thermal Energy Systems | 3 CR |
| M-ETIT-103802 | Adaptive Optics | 3 CR |
| M-ETIT-103450 | Digital Signal Processing in Optical Communications – with Practical Exercises | 6 CR |
| M-PHYS-102295 | Theoretical Nanooptics | 6 CR |
| M-ETIT-103270 | Optical Networks and Systems | 4 CR |
| M-ETIT-105461 | Introduction to Automotive and Industrial Lidar Technology<br>*First usage possible from Apr 01, 2022.* | 3 CR |
| M-ETIT-105914 | Photonic Integrated Circuit Design and Applications<br>*First usage possible from Apr 01, 2022.* | 6 CR |
| M-PHYS-106508 | Quantum Optics at the Nano Scale, with Exercises<br>*First usage possible from Apr 01, 2023.* | 8 CR |
| M-PHYS-106510 | Quantum Optics at the Nano Scale, without Exercises<br>*First usage possible from Apr 01, 2023.* | 6 CR |
| M-FORUM-106753 | Supplementary Studies on Science, Technology and Society neu<br>*First usage possible from Oct 01, 2024.* | 16 CR |

# I. Preamble

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 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 the sensor systems 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 close to industry 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, Quantum Optics & Spectroscopy, Biomedical Photonics, Optical Systems, and Solar Energy.

KIT Karlsruhe Institute of Technology

KSOP Karlsruhe School of Optics & Photonics

# II. Studies Plan (in accordance with SPO 2015 and statutes for the amendment of the Study and Examination Regulations 2019)

## 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 consists of 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 (1$^{st}$ Semester) and core-subject (2$^{nd}$ Semester) phases,
- research-oriented acquisition of competences in one of the interdisciplinary research areas of KSOP during the specialization phase (3$^{rd}$ Semester) and the master’s thesis (4$^{th}$ Semester),
- imparting of practical skills in scientifically oriented laboratory courses (1$^{st}$ and 2$^{nd}$ Semester) and an internship in industry or a research institution (2$^{nd}$ and 3$^{rd}$ Semester),
- acquisition of soft skills in the 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 develop 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 of familiarizing themselves with adjacent subject areas and their methods,
- have the competence to handle research- and application-oriented projects to a wide extent 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 combination 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'.

KIT Karlsruhe Institute of Technology

KSOP Karlsruhe School of 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.

| Master of Science in „ Optics & Photonics "<br>Exemplary Curriculum Overview | | | | | Total CP<br>120 |
|---|---|---|---|---|---|
| 1st term (Introduction) | | | | | |
| **Subject** | **Module<br>[ Module Identifier]** | **Term<br>W/S** | **Examination achievements** | **Study achievements** | |
| Physical "Optics & Photonics" | Fundamentals of Optics and Photonics [M-PHYS-101927] | W | written | | 8 CP |
| Engineering "O&P" | Electromagnetics and Numerical Calculation of Fields [M-ETIT-100386] | W | written | | 4 CP |
| | Optical Engineering [M-ETIT-100456] | W | oral | | 4 CP |
| Adjustment Course "O&P" (only one module, decided by KSOP Office) | Measurement and Control Systems [M-MACH-101921] | W | written | | 6 CP |
| | Modern Physics [M-PHYS-101931] | W | written | | 6 CP |
| O&P Lab I | Optics and Photonics Lab [M-PHYS-102189] | W/S | | ✓ | 5 CP |
| Interdisciplinary Qualification | e.g. Language courses at SpZ | W/S | another type | | 6 CP |

| 2nd term (Core subjects) | | | | | |
|---|---|---|---|---|---|
| **Subject** | **Module [ Module Identifier]** | **Term W/S** | **Examination achievements** | **Study achievements** | |
| Advanced Optics & Photonics – Theory and Materials | Theoretical Optics [M-PHYS-102280] | S | written | | 4 CP |
| | Nonlinear Optics [M-ETIT-100430] | S | oral | | 4 CP |
| Advanced Optics & Photonics – Methods and Components | Optoelectronic Components [M-ETIT-100509] | S | oral | | 4 CP |
| | Fabrication and Characterization of Optoelectronic Devices [M-ETIT-101919] | S | written | | 3 CP |
| | Spectroscopic Methods [M-CHEMBIO-101900] | S | written | | 3 CP |
| O&P Lab II | Optics and Photonics Lab [M-PHYS-102189] | W/S | | ✓ | 5 CP |
| Adjustment Course "O&P" | Basic Molecular Cell Biology [M-CHEMBIO-101903] | S | | ✓ | 2 CP |
| Internship | Internship in a company or institution (min. 8 weeks) [M-ETIT-102360] | to be arranged by the students themselves | | ✓ | 12 CP |

| 3rd term (Specialization) | | | | | |
|---|---|---|---|---|---|
| **Subject** | **Module [ Module Identifier]** | **Term W/S** | **Examination achievements** | **Study achievements** | |
| Specialization Photonic Materials and Devices | Optical Transmitters and Receivers [M-ETIT-100436] | W | oral | | 6 CP |
| | Quantum Optics [M-PHYS-103093] | W | oral | | 4 CP |
| | Solid-State Optics, without Exercises [M-PHYS-102408] | W | oral | | 6 CP |
| | | | | | Total 16 CP |

| Subject | Module [ Module Identifier] | Term W/S | Examination achievements | Study achievements | |
|---|---|---|---|---|---|
| Specialization Quantum Optics& Spectroscopy | Quantum Optics [M-PHYS-103093] | W | oral | | 4 CP |
| | Nano-Optics [M-PHYS-102146] | W | oral | | 6 CP |
| | Solid-State Optics, without Exercises [M-PHYS-102408] | W | oral | | 6 CP |
| | | | | | Total 16 CP |
| Specialization Biomedical Photonics | Advanced Molecular Cell Biology [M-CHEMBIO-101904] | W | written | | 5 CP |
| | Optics and Vision in Biology [M-CHEMBIO-101906] | W | written | | 4 CP |
| | Laser Physics [M-ETIT-100435] | W | oral | | 4 CP |
| | Optical Systems in Medicine and Life Science [M-ETIT-103252] | S | | ✓ | 3 CP |
| | | | | | Total 16 CP |
| Specialization Optical Systems | Systems and Software Engineering [M-ETIT-100537] | W | written | | 4 CP |
| | Field Propagation and Coherence [M-ETIT-100566] | W | oral | | 4 CP |
| | Laser Physics [M-ETIT-100435] | W | oral | | 4 CP |
| | Light and Display Engineering [M-ETIT-100512] | W | oral | | 4 CP |
| | | | | | Total 16 CP |
| Specialization Solar Energy | Solar Energy [M-ETIT-100524] | W | written | | 6 CP |
| | Plastic Electronics / Polymer Electronics [M-ETIT-100475] | W | oral | | 3 CP |
| | Electric Power Generation and Power Grid [M-ETIT-101917] | W | oral | | 3 CP |
| | Research Project [M-PHYS-102194] | W | | ✓ | 4 CP |
| | | | | | Total 16 |

| | | | | | CP |
|---|---|---|---|---|---|
| **Subject** | **Module [ Module Identifier]** | **Term W/S** | **Examination achievements** | **Study achievements** | |
| Seminar Course | Seminar Course [M-PHYS-102195] | W | | ✓ | 4 CP |
| Interdisciplinary Qualification | Sustainability Spring Days at KIT | W | | ✓ | 2 CP |
| Internship | Internship in a company or institution (min. 8 weeks) [M-ETIT-102360] | to be arranged by the students themselves | | ✓ | 12 CP |

| **4th term (Thesis)** | | | | | **Total 30 CP** |
|---|---|---|---|---|---|
| **Subject** | **Module [ Module Identifier]** | **Term W/S** | **Examination achievements** | **Study achievements** | |
| Master Thesis | Master Thesis (6 months) [M-ETIT-106212] | summer term (starting point to be arranged by the students themselves) | another type | | 30 CP |

| **Color legend** | |
|---|---|
| Compulsory module | The students must complete this specific module |
| Required elective module | The students can choose this module among all elective modules in the subject |
| Example of alternative time slots | The internship can be completed in the entire duration of study |
| Specialization – grade included in the overall grade | The students must complete 1 out of 5 specializations and collect at least 16 CP. The average grade of the specialization subject will be included in the overall grade |
| Grade **not** included in the overall grade | The grade of the subject will not be included in the overall grade |
| Grade included in the overall grade | The grade of the subject will be included in the overall grade |

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).

KIT Karlsruhe Institute of Technology

KSOP Karlsruhe School of Optics & Photonics

For details on the relevance of the subjects for the master's exam see also 'Studies and Exam Regulations' (SPO 2015) §19 and "Statutes for the Amendment of the Study and Examination Regulations" (2019) point seven. 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 of an Adjustment Course, compulsory modules on fundamental topics and first practical experiences in a lab course.

#### Adjustment Course

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 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 fundamental knowledge in natural sciences: systems theory, information acquisition and measurement, as well as design of controllers to manipulate the system state,
- 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.

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' and 'Engineering Optics & Photonics'.

#### Physical Optics & Photonics

'Physical Optics & Photonics' consists of the module 'Fundamentals of Optics and Photonics' 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**

'Engineering Optics & Photonics' consists of the modules 'Electrodynamics and Numerical Calculation of Fields' and 'Optical Engineering'.

***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 students will learn the basics of numerical field calculation using appropriate software packages,
- 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.

**Optics and Photonics Lab**

The students will get a first hands-on experience in basic optics and measurement techniques in the 'Optics and Photonics Lab'. A wide range of optical experiments have been selected from the advanced laboratory courses of the KSOP departments to broaden the students' theoretical knowledge from the fundamental courses. This subject consists of the two modules **O&PL I** in the winter semester and **O&PL II** in the summer semester. Additionally, the students are introduced to the principles of good scientific practice as a compulsory part of the course.

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

- the students learn how to prepare and carry out experiments, analyze the obtained data as well as how to summarize and discuss their results in a scientific report.

**Interdisciplinary Qualification**

Karlsruhe School of Optics & 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 the 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 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: www.hoc.kit.edu and Center for Cultural and General Studies ZAK: www.zak.kit.edu.
Wide spectrum of soft-skill courses, see also recommended courses in 'Detailed Curriculum' and module descriptions. Language Courses in English or the students' native language are excluded.

## *2nd Semester (Core-Subjects)*

The core-subjects phase has the goal of providing a comprehensive education in advanced optics and photonics and simultaneously give an overview 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.

**Advanced Optics & Photonics – Theory and Materials**

The subject 'Advanced Optics & Photonics – Theory and Materials' consists of the modules: 'Theoretical Optics' and 'Nonlinear Optics'.

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

- the students deepen their knowledge of 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,
- 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.

KIT Karlsruhe Institute of Technology

KSOP Karlsruhe School of Optics & Photonics

### Advanced Optics & Photonics – Methods and Components

The subject 'Advanced Optics & Photonics – Methods and Components' (AO&P-MC) consists of the modules 'Spectroscopic Methods', 'Optoelectronic Components' and 'Fabrication and Characterization of Optoelectronic Devices'.

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

- the students get introduced to various methodologies of molecular spectroscopy in frequency and time domain, to the interpretation of the respective optical spectra and to their application in various fields. They gain knowledge on spectroscopic equipment and optical components for the respective spectroscopic and/or microscopic technique,
- the students will comprehend the physical basis of optical communication systems enabling them to read a device's data sheet, to make the most of its properties, and to avoid hitting its limitations.
- 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 and disadvantages of different technological approaches, including their economic boundary conditions.

### Adjustment Course – Basic Molecular Cell Biology

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 have a background in biology, the adjustment course 'Basic Molecular Cell Biology' is compulsory for all.

***Objectives of Adjustment Course – Basic Molecular Cell Biology are:***

- students 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**'. For a description of the objectives see 1st semester subjects.

### Internship

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. – whether in a research related environment like at a university, a Fraunhofer Institute, industrial research lab or 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. Alternatively, the Internship can also be scheduled after the 3rd semester.

***Objectives of the Internship* are:**

- the students shall be exposed to the Optics & 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

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

- ‘Photonic Materials and Devices’
- ‘Quantum Optics & Spectroscopy’
- ‘Biomedical Photonics’
- ‘Optical Systems’
- ‘Solar Energy’

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’ 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,
- 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,
- 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,
- 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,
- 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.

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

The ‘Seminar Course’ serves as an integral module on key competencies and provides the students with a broad overview 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 students’ 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 3$^{rd}$ semester by ‘Additional Key Competencies’. For objectives see 1$^{st}$ semester subjects.

## $4^{th}$ Semester (Master's Thesis)

The master's thesis is a central element of the students' scientific specialization and building of an academic profile.

**Master's Thesis**

An overall time of six months 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 students to in depth scientific working methods. They learn to analyze 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.

Preconditions for the registration of a master's thesis are regulated in § 14(1) of the SPO (2015) and Article 1 in the Fifth Statute for the Amendment of the Study and Examination Regulations of the Karlsruher Institute of Technology for the M.Sc. Optics & Photonics. The thesis can only be started when there is a maximum of two exams left to complete. The student has to complete the first semester adjustment course (either Modern Physics or Measurement and Control Systems), the internship, the O&P labs and the seminar course before starting the master's thesis. The thesis has to be registered at the latest three months after the last module examination.

For the registration of the thesis, find a KSOP-advisor who will have the role of Examiner. The necessary Second Examiner can be fixed prior the final thesis is submitted. The Second Examiner is usually identified by the Examiner. The examiner needs to sign the supervision agreement (can be found on ILIAS). The filled in supervision agreement (original) has to be returned to the KSOP Examination Office (Dr. Jurana Hetterich) and a copy has to be handed in to the institute. An external master's thesis needs to be approved by the KSOP Examination Board (Prof. Neumann = head of KSOP Examination Board).

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').

KIT Karlsruhe Institute of Technology

KSOP Karlsruhe School of Optics & Photonics

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 Certificate of admission. The supervisor needs to hand in the green form to the 'Studierendenservice' and a copy to the Examination Board office.

The master's thesis must 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

| Contact Persons | Contact Details | Address |
|---|---|---|
| **Dr.-Ing. Judith Elsner**<br>KSOP Manager International Department | **E-Mail:** judith.elsner@kit.edu<br>Office: +49 (0)721 608 -47881 | Schloßplatz 19<br>Geb. 02.95 |
| **Prof. Dr. Uli Lemmer**<br>KSOP Coordinator | **E-Mail:** uli.lemmer@kit.edu<br>Office: +49 (0)721 608 - 42531 | Engesserstrasse 13<br>Geb. 30.34, room 223 |
| **Prof. Dr. Carsten Rockstuhl**<br>Dean of Studies<br>Research Project | **E-Mail:** carsten.rockstuhl@kit.edu<br>Office: +49 (0)721 608 - 46054 | TFP, Wolfgang-Gaede-Str. 1<br>Physikhochhaus<br>10th floor, room 23 |
| **Prof. Dr. Cornelius Neumann**<br>Head of Examination Board | **E-Mail:** cornelius.neumann@kit.edu<br>Office: +49 (0)721 608 - 46052 | LTI, Engesserstraße 13,<br>Geb. 30.34, room 221 |
| **Dr. Jurana Hetterich**<br>Office of Examination Board | **E-Mail:** ExaminationOffice-KSOP@idschools.kit.edu<br>Office: +49 721 608 - 42541 | LTI, Engesserstraße 13,<br>Geb. 30.34, room 224 |
| **Nina Becker**<br>M.Sc. Program Manager & Admissions | **E-Mail:** nina.becker@kit.edu<br>Office: +49 (0)721 608 – 45789 | Schloßplatz 19<br>Geb. 02.95 |
| **Dr. Nils Rosemann**<br>Scientific Advisor Seminar Courses<br>Mentor Ph.D. program | **E-Mail:** nils.rosemann@kit.edu<br>Office: +49 (0)721 608 - 26839 | IMT, Hermann-von-Helmholtz-Platz 1,<br>Eggenstein-Leopoldshafen |
| **PD Dr. Michael Hetterich**<br>Lab Coordinator | **E-mail:** michael.hetterich@kit.edu<br>Office: +49 721 608 - 43402 | Wolfgang-Gaede-Str. 1 Physikhochhaus<br>5th floor, room 5-15b |
| **Dr. Sylvia Lange**<br>Ph.D. Program Manager | **E-mail:** sylvia.lange@kit.edu<br>Office: +49 721 608 - 47879 | Schloßplatz 19<br>Geb. 02.95 |

## Lab Descriptions

**Optics and Photonics Lab I + II**

**Coordination:**
PD Dr. Michael Hetterich
(Department of Electrical Engineering and Information Technology /
Department of Physics)

**Content and organization:**

This laboratory course consists of a series of optical experiments selected from the advanced laboratory courses of the Departments of Physics, Electrical Engineering and Information Technology, Mechanical Engineering, as well as Chemistry and Biosciences. Additionally, the students are introduced to the principles of good scientific practice as a compulsory part of the course. The lab participants 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 a specific lab, they will acquire a certain number of lab units, where one lab unit roughly corresponds to a workload of half a day. Students have to collect 15 lab units in total over the course of two semesters, of which the students must choose at least three lab units from the Department of Physics and at least five lab units from the Department of Electrical Engineering. The labs will be marked with "+" (passed and above average) / "0" (passed) / "-" (failed). In case of "-", no lab units will be acquired. The choice of labs must be made at the beginning of each semester after attending the compulsory lab introduction by the coordinator (michael.hetterich@kit.edu), where details of the registration process will be given. Upon completion of the whole course, the O&P lab will award 10 credit points (5 per semester).

**Topics and lab objectives:**

1. **Quantum eraser (Department of Physics) (2 lab units)**
   **[currently not available]**

   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.

2. **Semiconductor spectroscopy (Department of Physics) (2 lab units)**
   **[currently not available]**

   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.

**3. 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.

**4. 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 set-up is aligned to make it lase, different spectra are taken, and the use/application of the laser is worked out.

**5. Optical tweezer (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.

**6. Magneto-optical Kerr effect – MOKE (Department of Physics) (2 lab units)**
**[currently not available]**

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.

**7. Laser spectroscopy (Department of Physics) (2 lab units)**

Optical spectroscopy can be used to stabilize a laser to an absolute frequency by taking advantage of the narrow linewidth of an atomic transition. A realization of such a laser stabilization is the Doppler-free saturation spectroscopy of rubidium atoms in a gas cell, which will be carried out in the scope of this experiment. The focus is on two fundamental methods in modern laser spectroscopy: absorption spectroscopy and Doppler-free saturation spectroscopy. The students will investigate and quantitatively evaluate the hyperfine structure of rubidium as well as learn the basic principles of handling a laser and optical devices.

**8. 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 $Tl^{205}$ is measured with high accuracy considering the dispersion of the spectrometer.

### 9. Optoelectronics laboratory (Department of Electrical Engineering and Information Technology) (8 lab units | series of 4 labs) [combined with "Nanotechnology laboratory"]

- Transmission measurement: This laboratory will deal with the measurement of transmission and reflection of optical filters. The students learn how to measure optical densities.
- Characterization of an organic laser: The laboratory is concerned with the theoretical basics and experimental techniques of optically pumped organic lasers. A special laser safety instruction is required.
- 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.

### 10. Nanotechnology laboratory (Department of Electrical Engineering and Information Technology) (8 lab units | series of 4 labs) [combined with "Optoelectronics laboratory"]

- 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 of how electron-beam microscopy works and where the benefits/limitations are. Furthermore, experience of building own nanostructures by electron-beam lithography will be obtained.
- OLED fabrication: The market of organic light-emitting diodes (OLEDs) has attracted a lot of attention in recent 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.
- 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 special laser safety instruction is required.
- 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.

**11. Lighting technology lab (Department of Electrical Engineering and Information Technology) (8 lab units | series of 4 labs)**

- Far-field goniometer lab (Eulumdat): In this experiment, the students work with the biggest test device in the Light Technology Institute. They 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 2 m and a weight of 50 kg.
- Near-field goniometer lab (Ray files): In this experiment, the students measure the full angle-resolved information of an LED. This data is the input for CAD simulations of non-imaging optics as used in general lighting applications today. This data set is used in the experiment “simulation of optical systems” afterwards.
- Thermal influence on the spectrum of an LED: It is well known, that LEDs will be the primary light sources for all lighting applications in the future. Therefore, it is important to know how their characteristics are influenced by one of the most important parameters, i.e., temperature.
- Simulation of optical systems: In this experiment, the students experience first contact with “light-tools”, one of the commonly used optical simulation tools based on ray tracing. In the tutorial, they build their own flashlight in virtual reality.

**12. Solar-energy laboratory (Department of Electrical Engineering and Information Technology) (8 lab units | series of 4 labs)**

- Fabrication and characterization of organic solar cells: In this experiment, the students will fabricate an organic solar cell by themselves in the cleanroom. They will do preparation of the substrate, structuring of the anode, spin coating of the polymers and evaporation of the metal cathode. Afterwards, they will measure the I–U characteristics of the manufactured organic solar cell and determine its efficiency.
- Modelling of organic solar cells: Here, the students simulate the electrical behavior of an organic solar cell and characterize its typical behavior.
- Quantum efficiency measurements of solar cells: In this experiment, the students try to determine the quantum efficiency of a Si cell with a measurement at lab conditions.
- Outdoor measurements of photovoltaic modules: In this experiment, the students learn the difference between measurements under lab conditions and the behavior under realistic conditions. We hope the sun will shine for the students!

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

This module provides 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.

**14. 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 network 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.

**15. BPM simulations of integrated optical waveguides (Department of Electrical Engineering and Information Technology) (2 lab units)**

High refractive index contrast waveguides are used in integrated optical devices. Typical single-mode planar and stripe waveguides are designed and characterized by beam propagation simulations with an industrial-standard high-frequency design suite. This gives a graphic understanding of the actual transmission of light as an electromagnetic wave, extension of optical fields and of what is meant by “optical mode”.

**16. 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.

**17. 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.

### 18. Optics design lab (Department of Electrical Engineering and Information Technology) (5 lab units | series of 5 labs) [summer term only]

The industry's demand for engineers with knowledge in the areas of optics and optics design has been continuously growing for years. Applications of optical systems can be found in a wide field of industries, from opto-electronics, communication, astronomy, and measurement technology to biomedical technology and consumer electronics. Therefore, there is a great demand for engineers with training in optical design. The aim of the Optics Design Lab is to teach students the basic skills for working with optical design and optimization tools:

- Simulation of simple optical elements (lenses, mirror, prism)
- Simulation of simple optical systems
- Imaging errors (aberrations)
- Evaluation of imaging quality of optical systems
- Computer-aided optimization of optical systems
- Fiber-optical systems and lasers
- Diffractive elements
- Illumination design

### 19. Optical waveguides (Department of Mechanical Engineering, Institute of Microstructure Technology) (2 lab units) [no longer available]

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 measurement techniques:

- 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)
- m-line spectroscopy (measurement of the effective mode indices for different wavelengths, demonstration of IWKB calculation method, defining the refractive index profile, the maximum index contrast and the decay constant depending on UV exposure)
- near-field intensity distribution (NFP) measurement (discussion of the mode order and mode field diameter of single mode waveguide structures)
- far-field intensity distribution (FFP) measurement (discussion of the far-field symmetry, the divergence angle and the calculation of numerical aperture (NA))
- 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. Mobile robot platform / machine vision (Department of Mechanical Engineering, MRT) (2 lab units) [winter term only]**

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.

**21. Femtosecond spectroscopy in solution (Department of Chemistry) (2 lab units) [summer term only]**

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.

**22. 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 $C_6H_6$ vs $C_6D_6$). Another focus is on the interpretation of vibrational Raman spectra.

**23. 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 processed and interpreted.

**24. 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 super luminescent diode (SLD) affects the axial resolution of OCT. Dispersion compensation and the Fourier transform of the interference spectrum will also be addressed. For this course, a laser safety instruction is required.

**25. Image processing for smart optical systems (Department of Electrical Engineering and Information Technology) (2 lab units | series of 2 labs) [summer term only]**

Artificial Intelligence (AI) is becoming increasingly important in the work of modern scientists. At the Institute for Information Processing Technologies (ITIV), AI has a history reaching back to the founder of the Institute Karl Steinbuch and his innovative "Learning Matrix" in 1961.
For the task of image processing, Convolutional Neural Networks (CNN) have proven highly effective. Deep learning frameworks are used to model those neural networks. In this lab, the students will learn about the inner workings of CNNs and their implementation to solve real world problems. Furthermore, they will learn how to use a state of the art deep learning framework for tackling problems like image classification and segmentation on pixel level using the so-called convolutional auto encoders.
Requirements: Experience in programming, preferably in Python.

**26. Fluorescence angiography (Institute of Biomedical Engineering, Department of Electrical Engineering and Information Technology) (2 lab units)**

This lab course introduces students to the practical use of fluorescent dyes in medicine and life science. Students will learn how to set up requirements for a fluorescence imaging system and will have hands on experience with a setup containing a blood flow phantom and the recording system. Later, the students will extract and analyze spatio-temporal parameters from the images obtained.

**27. Fluorescence correlation spectroscopy (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.

**28. Photon count statistics (Department of Physics) (2 lab units)**

This lab provides an introduction to one of the standard methods used in experimental quantum optics known as photon count statistics. Students will investigate the quantum description of light coherence in the form of photon count distributions and verify that coherent light from lasers and thermal light give different photon statistics when detected with a single-photon detector.

**29. Quantum optics (Department of Physics) (2 lab units)**

In this experiment, quantum properties of light are investigated. Single photons are generated, detection techniques are illustrated and basic quantum-mechanical concepts such as the superposition of states are demonstrated.

**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 provided on ILIAS or by the supervisor of the individual lab.

**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:**

| | | |
|---|---|---|
| Dep. of Physics | interview | 33 % |
| | lab work | 33 % |
| | experiment report/data interpretation | 33 % |
| Dep. of Elec. Eng. | interview/lab work | 50 % |
| | experiment report/closing meeting | 50 % |
| Dep. of Mech. Eng. | lab work | 70 % |
| | experiment report/data interpretation | 30 % |
| Dep. of Chemistry/ Biology | interview/lab work | 50% |
| | experiment report/data interpretation | 50% |

**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 or provided on ILIAS.

**Literature:**

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

## Contact:

**Department of Physics**

Name: Lilyn Gao (LAB 3+4)
Tel. : 0721 / 608-26964
E-mail: jingya.gao@kit.edu

Name: Amirhossein Barati Sedeh (LAB 5+27)
Tel. : 0721 / 608-45820
E-mail: amirhossein.sedeh@kit.edu

Name: Dr. Christoph Sürgers (LAB 6+7+8)
Tel. : 0721 / 608-43456
E-mail: christoph.suergers@kit.edu

Name: Vishnu Unni Chorakkunnath (LAB 28)
E-mail : vishnu.chorakkunnath@kit.edu

Name: András Laukó (LAB 29)
Tel. : 0721 / 608- 47016
E-mail: andras.lauko@partner.kit.edu

**Department of Electrical Engineering and Information Technology**

Name: Dr.-Ing. Klaus Trampert (LAB 9+10+11+12)
Tel. : 0721 / 608-47065
E-mail: klaus.trampert@kit.edu

Name: Dr. Artem Kuzmin (LAB 13+14+15+16+17)
Tel. : 0721 / 608-42496
E-mail: artem.kuzmin@kit.edu

Name: Lintao Toni Fan (LAB 18)
Tel. : 0721 / 608-41309
E-mail: lintao.fan@kit.edu

Name: Julia Hofmann (LAB 25)
Tel. : 0721 / 9654-766
E-mail: Hofmann2@fzi.de

**Department of Mechanical Engineering:**

Name: Alexander Blumberg (LAB 20)
Tel. : 0721 / 608-43174
E-mail: alexander.blumberg@kit.edu

**Department of Chemistry and Biosciences**

Name: Prof. Dr. Andreas-Neil Unterreiner (LAB 21)
Tel. : 0721 / 608-47807
E-mail: andreas.unterreiner@kit.edu

Name: Dr. Sergei Lebedkin (LAB 22)
Tel. : 0721 / 608-26391
E-mail: sergei.lebedkin@kit.edu

Name: Dr. Franco Weth (LAB 23)
Tel. : 0721 / 608-44849
E-mail: franco.weth@kit.edu

**Institute of Biomedical Engineering**

Name: Simon Hoffmann (LAB 24)
Tel. : 0721 / 608-42751
E-mail: simon.hoffmann2@kit.edu

Name: Miriam Weiß (LAB 26)
Tel. : 0721 / 608-41579
E-mail: miriam.weiss@kit.edu

# 6 Modules

## M 6.1 Module: Adaptive Optics [M-ETIT-103802]

**Responsible:** Dr. Szymon Gladysz
Prof. Dr. Ulrich Lemmer

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Specialization / Specialization - Photonic Materials and Devices (Usage from 4/1/2018)
Specialization / Specialization - Biomedical Photonics (Compulsory Elective Modules)
Specialization / Specialization - Optical Systems
Specialization / Specialization - Quantum Optics & Spectroscopy
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each winter term | 1 term | English | 4 | 3 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-107644 | Adaptive Optics | 3 CR | Gladysz, Lemmer |

**Competence Certificate**
Type of Examination: Oral examination

Duration of Examination: approx. 30 Minutes

Modality of Exam: The oral exam will be scheduled during the semester break.

**Prerequisites**
None.

**Competence Goal**
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**
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.

1. Theory of turbulence (covariances, structure functions, power spectra, inertial range, dimensional argument of Kolmogorov)
2. Fourier optics (point-spread function, modulation transfer function)
3. Statistical optics (characteristic function, probability density function)
4. Sources and description of aberrations (Zernike polynomials, orthogonality, Marechal criterion)
5. Adaptive optics systems (open- and closed-loop systems, error budgets, tip-tilt correction)
6. Wavefront sensing (Shack-Hartmann wavefront sensor, wavefront reconstruction, wavefront-sensorless AO)
7. Wavefront correction (tip-tilt mirrors, deformable mirrors, piezoelectric effect, microelectromechanical systems, electrostatic actuation)
8. Simulation of adaptive optical systems (analytic vs. end-to-end modelling)
9. Propagation of laser beams through atmospheric turbulence (Gaussian beams, Rytov theory, scintillation index, beam wander)
10. Modelling of free-space optical communication systems (aperture averaging, mean signal-to-noise ratio, false-alarm rate and fade probability, bit error-rate)

**Module grade calculation**
The module grade is the grade of the oral exam.

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

**Recommendation**
Basic knowledge of statistics.

**Literature**
Robert K. Tyson, Principles of Adaptive Optics, CRC Press

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

## M 6.2 Module: Advanced Inorganic Materials [M-CHEMBIO-101901]

**Responsible:** Prof. Dr. Claus Feldmann
**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Quantum Optics & Spectroscopy
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each summer term | 2 terms | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-CHEMBIO-103591 | Advanced Inorganic Materials | 3 CR | |

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 30 min

Modality of Exam: The oral exam is scheduled at the end of the semester.

**Prerequisites**
No formal prerequisite, but continous presence in the lecture is strongly recommended.

**Competence Goal**
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 Egyption 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

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

**Recommendation**
Basic knowledge in chemistry.

**Literature**
A. WEST (current edition): Solid State Chemistry and its Applications, Wiley.
A. GREENWOOD, N. EARNSHAW (current edition), Chemistry of the Elements, Elsevier.
U. MÜLLER (current edition): Inorganic Structural Chemistry, Teubner.
J. E. HUHEEY, E. A. KEITER (current edition): Inorganic Chemistry, Pearson.
Selected reviews (as given in the lecture).

# M 6.3 Module: Advanced Molecular Cell Biology [M-CHEMBIO-101904]

**Responsible:** Prof. Dr. Martin Bastmeyer
Dr. Franco Weth

**Organisation:** KIT Department of Chemistry and Biosciences

**Part of:** Specialization / Specialization - Biomedical Photonics (Compulsory Modules)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 5 | Grade to a tenth | Each winter term | 1 term | English | 4 | 3 |

| Mandatory | | | |
|---|---|---|---|
| T-CHEMBIO-105196 | Advanced Molecular Cell Biology | 5 CR | Weth |

**Competence Certificate**
Type of Examination: written (or oral)

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

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.

**Prerequisites**
none

**Competence Goal**
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 flourophores,
• 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

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

**Recommendation**
Passed exam of the Adjustment Course in “Basic Molecular Cell Biology”.

**Learning type**
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.

**Literature**
Molecular Biology of the Cell, Alberts, B., et al., Taylor & Francis, 6th ed., 2014
Molecular Cell Biology, Lodish, H., et al., Macmillan, 2013

## 6.4 Module: Automotive Vision [M-MACH-102693]

**Responsible:** Dr. Martin Lauer
Prof. Dr.-Ing. Christoph Stiller

**Organisation:** KIT Department of Mechanical Engineering

**Part of:** Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each summer term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-MACH-105218 | Automotive Vision | 4 CR | Lauer, Stiller |

**Competence Certificate**
Type of Examination: Written exam

Duration of Examination: 60 Minutes

Modality of Exam: One written exam offered at the end of each semester.

**Prerequisites**
None

**Competence Goal**
After having participated in th lecture the participants have gained knowledge on modern techniques of signal processing and artificial intelligence which can be used to evaluate video sequences, to relate the image content to a spatial context and to interpret the content semantically. This comprises, binocular reconstruction, recognition of movements in video sequences, state space modeling and Bayesian filters, and the recognition of road surfaces and object behavior. The participants have learned to analyze the algorithms mathematically, to implement them in software, and to apply them to tasks in autonomous driving and mobile robots. The participants are able to analyze problems in the areas mentioned before and to develop appropriate solutions.

**Content**
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.

**Workload**
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h computer exersice) and 75 h homework and self-studies

**Recommendation**
None, but knowledge in Machine Vision is useful.

**Learning type**
Lecture

**Literature**
TBA

## M 6.5 Module: Basic Molecular Cell Biology [M-CHEMBIO-101903]

**Responsible:** Prof. Dr. Martin Bastmeyer
Dr. Franco Weth
**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** Adjustment Courses (mandatory)

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 2 | pass/fail | Each summer term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-CHEMBIO-105199 | Basic Molecular Cell Biology | 2 CR | Weth |

**Competence Certificate**
The written exam over 120 Minutes is scheduled for the beginning of the break after the SS.

**Prerequisites**
none

**Competence Goal**
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

**Workload**
Working hours in total are 60 hours for an average student. Thereof 30 h (= approx. 14 x 2h) attendance in lectures and 30 h self-study as preparation for the exam.

**Learning type**
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.

**Literature**
Lecture presentations will be accessible in pdf-format.
Essential cell biology, Alberts, B., et al., Taylor & Francis, 4th ed., 2013
Principles of Cell Biology, Plopper, G., Jones & Bartlett Publ., 2011
Prerequisites

# 6.6 Module: Business Innovation in Optics and Photonics [M-ETIT-101834]

**Responsible:** Prof. Dr. Werner Nahm
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Interdisciplinary Qualifications
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-104572 | Business Innovation in Optics and Photonics | 4 CR | Nahm |

**Competence Certificate**
Type of Examination: examination of another type

Duration of Examination: 4 group presentations à 20 minutes (approx.)

Modality of Exam: The exam consists of four group presentations. 2nd day: Technology Presentation. 3rd day: Development plan presentation. 4th day: Business Canvas presentation. Final presentation at Zeiss visit: Business pitch

**Prerequisites**
none

**Competence Goal**
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 studetns

- 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?
- Management of Intellectual Property (IP): Importance of IP Management, Patent research, Patent claims, Licencing, Patent infringement, Patent litigation
- 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

**Module grade calculation**
The final grade is the weighted average of the gradings for the four presentations. The three intermediate presentations are each weighted 1, the final presentation is weighted 3.

**Workload**
total 120 h, thereof 34 h contact hours and 86 h preparation, homework, self-studies and excursion

**Recommendation**

Good knowledge in optics & photonics. Personal motivation and interest for getting deeper into business development aspects, methods and tools. Commitment to active, regular and coninuous participation in the group work.

# M 6.7 Module: Computational Photonics, without ext. Exercises [M-PHYS-103089]

**Responsible:** Prof. Dr. Carsten Rockstuhl
**Organisation:** KIT Department of Physics
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Specialization / Specialization - Solar Energy (Compulsory Elective Modules)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Irregular | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-106131 | Computational Photonics, without ext. Exercises | 4 CR | Rockstuhl |

**Competence Certificate**
Type of Examination: oral examination (study and exam regulations §4 (2)2.)

Duration of Examination: approx. 30 minutes

**Prerequisites**
none

**Competence Goal**
The students can use a computer to solve optical problems and can use a computer to visualize details of the light matter interaction, know different strategies to solve Maxwell's equations on rigorous grounds, know 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, can implement programs with a reasonable complexity by themselves, can use a computer to discuss and explore optical phenomena, and are familiar with basic computational strategies that emerge in photonics, but comparably in any other scientific discipline as well.

**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

**Annotation**
For students of the KIT Faculty of Computer Science: The exams in this module have to be registered via admissions from ISS (KIT Faculty of Computer Science). For this, an e-mail with matriculation number and name of the desired exam to Beratung-informatik@informatik.kit.edu is sufficient.

**Workload**
total 120 h, hereof 45 h contact hours, (30 h lecture, 15 h labwork class), and 75 h homework and self-studies

**Recommendation**
Interest in theoretical physics, optics and electrodynamics. Moreover, interest in computational aspects is important.

**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

Specific references for the individual topics will be given during the lectures.
The lecture material that will be fully made available online.

## M 6.8 Module: Digital Signal Processing in Optical Communications – with Practical Exercises [M-ETIT-103450]

**Responsible:** Prof. Dr.-Ing. Sebastian Randel
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Optical Systems (Usage from 4/1/2018)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Each summer term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-106852 | Digital Signal Processing in Optical Communications – with Practical Exercises | 6 CR | Randel |

**Competence Certificate**
The exercise sheets and the oral questionnaire are used to rate other types of examinations. The overall impression is assessed. Duration about 20 minutes.

**Prerequisites**
Basic knowledge of optical communication systems. Proven, for example, by completing one of the modules "Optical Networks and Systems-ONS", "Optoelectronic Components -OC, or" Optical Transmitters and Receivers - OTR.

**Competence Goal**

- The students understand the functioning of modern optical communication systems, which combine electro-optical technologies with digital signal processing.
- You are able to independently implement and test algorithms from digital signal processing as well as suitable simulation and test environments in a suitable scripting language (e.g. Matlab or. Python).
- Furthermore, they can estimate the influence of interfering effects occurring in the glass fiber such as chromatic dispersion and polarization mode dispersion.
- You are also able to estimate the complexity and power consumption of the resulting logic circuits.

**Content**

- The module deals with algorithms from digital signal processing that are used in broadband optical communication systems. Practical exercises in which the students implement algorithms independently form an essential part of the module.
- In lectures there will be an introduction to the development of digital coherent transmitters and receivers. Building on this, essential function blocks such as the dispersion compensation, the adaptive equalization of polarization mode dispersion as well as carrier and clock recovery are discussed.
- In the exercises, these function blocks are to be implemented in software (Matlab, Octave).
- In addition, individual examples show how digital signal processing algorithms are described in hardware (Hardware Description Language - HDL) and how their complexity scales.

**Module grade calculation**
The exercise sheets and the oral questioning are used to rate other types of examinations. The overall impression is assessed.

**Workload**
Approximately 170h workload of the student. The workload includes:

30h - attendance in lectures

30h - exercises

70h - preparation / follow-up

40h - written exercises and exam

**Recommendation**
Knowledge of the basics of optical communication technology and digital signal processing is helpful.

# M 6.9 Module: Electric Power Generation and Power Grid [M-ETIT-101917]

**Responsible:** Dr.-Ing. Bernd Hoferer
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Solar Energy (Compulsory Elective Modules)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-103608 | Electric Power Generation and Power Grid | 3 CR | Hoferer |

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 20 minutes

**Prerequisites**
none

**Competence Goal**
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

**Module grade calculation**
The module grade is the grade of the oral exam.

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

**Recommendation**
none

**Literature**
Schwab; Electric energy systems;
Fink, Beaty; Standard handbook for electrical engineers

# M 6.10 Module: Electromagnetics and Numerical Calculation of Fields [M-ETIT-100386]

**Responsible:** Prof. Dr.-Ing. Thomas Zwick
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Engineering Optics & Photonics

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-100640 | Electromagnetics and Numerical Calculation of Fields | 4 CR | Zwick |

**Competence Certificate**
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.

**Prerequisites**

**Competence Goal**
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, field 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 potential and Vector potential 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, Method of Moments (MOM), Transmission LIne Matrix Methal (TLM),

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.

**Module grade calculation**

The module grade is the grade of the written exam.

**Workload**

total 120 h, hereof 45h contact hours (30h lecture, 15h problem class), and 75h homework and self-studies

**Recommendation**

Participation in the exercises is recommended to qualify for the written exam. One exercise sheet is handed out to the students as homework fortnightly.

Fundamentals of electromagnetic field theory.

Solid mathematical background, basic knowledge in electric and magnetic fields.

**Literature**

Matthew Sadiku (2001), Numerical Techniques in Electromagnetics.
CRC Press, Boca Raton, 0-8493-1395-3
Allen Taflove and Susan Hagness (2000), Computational electrodynamics: the finite-difference time-domain method.
Artech House, Boston, 1-58053-076-1
Nathan Ida and Joao Bastos (1997), Electromagnetics and calculation of fields.
Springer Verlag, New York, 0-387-94877-5
Z. Haznadar and Z. Stih (2000), Electromagnetic Fields, Waves and Numerical Methods.
IOS Press, Ohmsha, 1 58603 064 7
M.V.K. Chari and S.J. Salon (2000), Numerical Methods in Electromagnetism, Academic Press, 0 12 615760 X

## M 6.11 Module: Fabrication and Characterisation of Optoelectronic Devices [M-ETIT-101919]

**Responsible:** Prof. Dr. Bryce Sydney Richards
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Advanced Optics & Photonics – Methods and Components

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each summer term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-103613 | Fabrication and Characterisation of Optoelectronic Devices | 3 CR | Richards |

**Competence Certificate**
Type of Examination: written exam

Duration of Examination: 120 Minutes

Modality of Exam: One written exam offered at the end of each semester.

**Prerequisites**
None.

**Competence Goal**
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 technologiccal-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 highthroughput 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. Characterissation:

- 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)

**Module grade calculation**
The module grade is the grade of the written exam.

**Workload**
Total 90 h, hereof 30 h contact hours (24 h lecture, 6 h problem class), and 60 h homework and self-studies.

**Recommendation**
Semiconductor fundamentals

**Literature**
TBD

## 6.12 Module: Field Propagation and Coherence [M-ETIT-100566]

**Responsible:** Prof. Dr. Wolfgang Freude
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-100976 | Field Propagation and Coherence | 4 CR | Freude |

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 30 minutes

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

**Prerequisites**
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.

**Competence Goal**
Presenting in a unified approach the common background of various problems and questions arising in general optics and optical comunications

The students

- knwo 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 multimode waveguides. Near-field and far-field. Impulse response and transfer function. Perurations and mode coupling. Multimode interference (MMI) coupler. Modal noise (speckle)
- Propagation in homogeneous media: Resolution limit. Non-paracial and paracial optics. Gaussian beam. ABCD matrix
- Coherence of optical fields: Coherence function and power spectrum. Polarisation, eigenstates and principal states. Measurement of coherence with interferometers (Mach-Zehnder, Michelson). Self-heterodyne and self-homodyne setups

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies

**Recommendation**
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:

Born, M.; Wolf, E.: Principles of optics, 6. Aufl. Oxford: Pergamon Press 1980

Ghatak, A.: Optics, 3. Ed. New Delhi: Tata McGraw Hill 2005

Hecht, E.: Optics, 2. Ed. Reading: Addison-Wesley 1974

Hecht, J.: Understanding fiber optics, 4. Ed. Upper Saddle River: Prentice Hall 2002

Iizuka, K.: Elements of photonics, Vol. I and II. New York: John Wiley & Sons 2002

Further textbooks in German (also in electronic form) can be named on request

# M 6.13 Module: Fundamentals of Optics and Photonics [M-PHYS-101927]

**Responsible:** Prof. Dr. David Hunger
**Organisation:** KIT Department of Physics
**Part of:** Physical Optics & Photonics

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 8 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-103630 | Fundamentals of Optics and Photonics - Unit | 0 CR | Hunger |
| T-PHYS-103628 | Fundamentals of Optics and Photonics | 8 CR | Hunger |

**Competence Certificate**
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. Atest exam is offered before the Christmas holidays.

**Prerequisites**
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.

**Competence Goal**
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 Matrizes; 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)

**Workload**
total 240 h, hereof 90h contact hours (60h lecture, 30h problem class), and 150h homework and self-studies

**Recommendation**
Solid mathematical background, basic knowledge in physics

**Learning type**
Lecture (including de-monstration experiments) and problem class

**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

## M 6.14 Module: Further Examinations [M-ETIT-102000]

**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 30 | pass/fail | Each term | 1 term | German | 4 | 1 |

# M 6.15 Module: Imaging Techniques in Light Microscopy [M-CHEMBIO-101905]

**Responsible:** Prof. Dr. Martin Bastmeyer
**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** Specialization / Specialization - Biomedical Photonics (Compulsory Elective Modules)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each winter term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-CHEMBIO-105197 | Imaging Techniques in Light Microscopy | 3 CR | Bastmeyer |

**Competence Certificate**
Written exam over 120 minutes (depending on the number of participants oral exam over approx.45 min).

Modality of Exam: Depending on the number of participants, a written or an oral 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.

**Prerequisites**
none

**Competence Goal**
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)

**Workload**
Total 90 h, hereof 30 h contact hours (30 h lecture), and 60 h homework and self-studies

**Recommendation**
Attendance to the lecture. Basic knowledge in physics and biology.

**Learning type**
Lecture (including demonstration of microscopic techniques in the laboratory)

**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

# 6.16 Module: Internship [M-ETIT-102360]

**Responsible:** Prof. Dr. Ulrich Lemmer
Prof. Dr.-Ing. Christoph Stiller

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Internship

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 12 | pass/fail | Irregular | 2 terms | English | 5 | 3 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-105127 | Internship Presentation | 12 CR | Lemmer, Stiller |

**Competence Certificate**
The internship is a study achievement (study and examinations Regulation, § 4 (3)). A minimum of working hours equivalent to 8 weeks of full-time work (excluding holidays and public holidays) must be completed.

Furthermore the following must be provided:

1: A company confirmation about the completion of the internship

**Internship confirmation/certificate from industry or research institute.**

The interns***h***ip confirmation is issued directly by the company or institute, respectively, after the internship is completed. 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 Name (institute, sector and supervisor). Please note that the internship contract is not valid as a certificate.

**2. Delivery of a written report on methodology and results (approx. 10 pages).**

The internship report comprises a written report in the form of a seminar paper and an evaluation to be handed in to the KSOP student office.

-> Both documents (company confirmation and internship report) have to be send to the KSOP Office latest 2 weeks before the presentation date.

3. **Presentation**

In the internship presentation the students have to present the project work of their internships to a KSOP professor and their peers (who make the presentation on the same day; usually up to 15 students) followed by a discussion of the results.

For the presentation several dates (usually one every three month) are available per year. The dates are announced twice a year to the current students and students need to register online for the desired presentation date latest 15 days before the desired presentation date. After that the registration will be closed.

The 12 credit points are awarded after passing the company confirmation, internship report and presentation. The decision is made by a KSOP professor.

**Prerequisites**
Scientific background in Optics and Photonics

**Competence Goal**
The students gather insight in procedures and practical work in industry or research institutions. They acquire hands-on experience in a concise practical task related to a future job profile in the field of Optics and Photonics, be it in research or industry. 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 an 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**
The students are 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.

**Workload**
total 360 h including 8-week (320 h) project work in industry plus 40 h of report

writing and presentation of results

**Recommendation**
Scientific background in Optics and Photonics

**Learning type**
Internship

**Literature**
Individual literature will be provided by the external internship advisor.

## M 6.17 Module: Introduction to Automotive and Industrial Lidar Technology [M-ETIT-105461]

**Responsible:** Prof. Dr. Wilhelm Stork
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Optical Systems (Usage from 10/1/2020)
Additional Achievements (Usage from 4/1/2022)

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-111011 | Introduction to Automotive and Industrial Lidar Technology | 3 CR | Stork |

**Competence Certificate**
The examination consists of an oral exam and a short oral presentation. The overall impression is rated.

**Competence Goal**

- The students are able to explain the basic principles of a lidar sensor
- The students can explain all relevant components of a lidar sensor and put them in context
- The students can explain different forms of execution and make a meaningful choice depending on the requirements
- The students can describe lidar sensors theoretically using the lidar equations and explain the interactions based on this theory
- The students are able to assess the eye safety of a system
- The students are able to suggest possible sensor concepts for different applications or to evaluate existing concepts

**Content**
In this course the functionality of a lidar sensor is explained and then put into context with relevant use cases. Typical criteria for the evaluation of the performance are then presented. In the following the concept of the sensor is presented in detail and all relevant components are introduced individually. Afterwards they are qualitatively related to each other and the whole system is quantitatively examined by means of the lidar equation. Finally, the interaction of the components is further considered to present meaningful combinations and design solutions. The eye safety of lidar sensors is always explicitly considered. The course concludes with a colloquium in which the students will give short presentations on what they have learned. This repetition is intended to repeat and deepen what has been learned and to lead to a discussion of open question

**Module grade calculation**
The module grade results of the assessment of the oral exam and the short oral presentation. Details will be given during the lecture.

**Workload**

1. participation in the lectures 12h - 8 dates á 1,5h
2. preparation and postprocessing 14 h ( 2h for VL dates 1-7 )
3. preparation of the short lecture (16h)
4. preparation and participation in the oral exam : 48h

**Recommendation**
Basics of optics / optical technologies are helpful (e.g. optical engineering, optoelectronic, technical optics)

## 6.18 Module: Introduction to the Scientific Method (Seminar, English) [M-ETIT-105665]

**Responsible:** Prof. Dr. Werner Nahm
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Interdisciplinary Qualifications (Usage from 4/1/2021)

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 1 | pass/fail | Each term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-111317 | Introduction to the Scientific Method (Seminar, Englisch) | 1 CR | Nahm |

**Competence Certificate**
The sucess control takes place in the form of a study achievement. The exam consists of the preparation and the presentation of a seminar paper.

**Prerequisites**
none

**Competence Goal**

- The students can describe and explain the scientific method using examples.
- The students can critically evaluate the implementation of the scientific method using the example of selected publications.
- The students can structure their own topic along the scientific method.
- The students can derive and formulate key questions and hypotheses on a research topic using their own example.

**Content**
The seminar is a combination of lecturer presentations and discussion, as well as student presentations and discussions

The block course consists of three parts:

Part 1: Basics and presentation of the method

Part 2: Applying the method to analyze selected examples

Part 3: Application of the method for structuring one's own research topic

The seminar deals with the questions:

- what is science?
- what is scientificy?
- what is the scientific method?
- what is a scientific design?

The seminar sheds light on classical and modern approaches to the theory of science, in particular critical rationalism.

The seminar develops definitions and delimitations of the terms:

- research topic
- leading question
- thesis
- hypothesis
- assumption
- theory

The seminar develops a simple and practical recipe for the scientific design of publications, theses and dissertations.

The recipe is used by the seminar participants to analyze selected scientific work and to structure their own scientific work.

**Module grade calculation**
The seminar is passed by successful submission and presentation of the seminar paper.

**Annotation**
The course is held as a block in the second half of each semester.

**Workload**

1. attendance times in lectures and exercises: 7 x 1,5h = 10,5h
2. preparation of lectures and exercises 7 x 1,5h = 10,5h
3. preparation of the seminar paper: 10h

# 6.19 Module: Laser Metrology [M-ETIT-100434]

**Responsible:** Prof. Dr. Marc Eichhorn
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Optical Systems
Specialization / Specialization - Quantum Optics & Spectroscopy
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each summer term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-100643 | Laser Metrology | 3 CR | Eichhorn |

**Competence Certificate**
Type of Examination: Oral examination

Duration of Examination: approx. 30 minutes

Modality of Exam: The oral exam is scheduled for the beginning of the break after the SS

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

**Competence Goal**
The students understand the fundamental properties of laser light and possess the knowledge necessary to understand the metrologically obtainable information, understand the basics of various detectors as well as their limits and have the knowledge necessary to understand a multitude of laser metrological setups, mainly for interferometry, Moiré methods, distance and velocity measurements and absorption as well as scattering techniques.

**Content**
In the module several aspects of laser diagnostics will be discussed, beginning with the fundamental properties of laser light and the related metrologically useful information. In addition beam diagnostics and interferometric setups in general, as well as Moiré methods in particular, will be discussed. Further topics of the lecture will be commonly used setups, mainly for laser distance and velocity measurements along with widely used absorption and scattered light methods.

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)

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
total 90 h, hereof 30 h contact hours (30 h lectures) and 60 h recapitulation and self-studies

**Recommendation**
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)

# 6.20 Module: Laser Physics [M-ETIT-100435]

**Responsible:** Prof. Dr. Marc Eichhorn
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Biomedical Photonics (Compulsory Elective Modules)
Specialization / Specialization - Optical Systems
Specialization / Specialization - Quantum Optics & Spectroscopy
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-100741 | Laser Physics | 4 CR | Eichhorn |

**Competence Certificate**
Type of Examination: Oral examination

Duration of Examination: approx. 30 minutes

Modality of Exam: The oral exam is scheduled for the beginning of the break after the WS.

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

**Competence Goal**
The students understand the fundamental relations and basics of a laser. They obtain the knowledge necessary for understanding and designing lasers (laser media, optical resonators, pumping schemes) and understand the basics and schemes for pulse generation in a laser. They have the knowledge needed for a multitude of lasers: gas, solid-state, fiber and disc lasers from the visible up to the mid-Infrared spectrum.

**Content**
Within the module the physical basics of lasers, the fundamental processes of light amplification and the formalisms necessary to describe lasers and laser resonators are covered. The generation of laser pulses and various laser architectures as well as realisations are presented in detail.

The exercises specifically discuss the topics of laser description, theoretical background as well as the realization of different laser designs. The tasks of the exercise will be handed out at the end of each lecture as well as uploaded to the lecture website and are to be solved for the following exercise, in which the solution will be discussed.

Contents:

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

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
total 120 h, hereof 45 h contact hours (30 h lectures, 15 h tutorial) and 75 h recapitulation and self-studies

**Recommendation**
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)

## 6.21 Module: Light and Display Engineering [M-ETIT-100512]

**Responsible:** Dr.-Ing. Rainer Kling
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-100644 | Light and Display Engineering | 4 CR | Kling |

**Competence Certificate**
Type of Examination: Oral exam

Duration of Examination: approx. 25 minutes

Modality of Exam: The oral exam is flexibly held by student request after the WS.

**Prerequisites**
none

**Competence Goal**
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)

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
total 120 h, hereof 45 h contact hours (lecture and tutorial), and 75 h homework and self-studies

**Recommendation**
Basic physics background

**Literature**

Simons, Lighting Engineering: Applied Calculations, 2001

Shunsuke Kobayashi: LCD Backlights, 2009

Winchip, Fundamentals of Lighting, 2nd Edition, 2011

Malacara, Handbook of Optical Design, 2004

## M 6.22 Module: Lighting Design - Theory and Applications [M-ETIT-100577]

**Responsible:** Dr.-Ing. Rainer Kling
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| **Mandatory** | | | |
|---|---|---|---|
| T-ETIT-100997 | Lighting Design - Theory and Applications | 3 CR | Kling |

**Competence Certificate**
Type of Examination: Oral exam

Duration of Examination: approx. 25 minutes

Modality of Exam: The oral exam is flexibly held by student request after the WS.

**Prerequisites**
None

**Competence Goal**
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

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
total 90 h, hereof 45 h contact hours (Seminar), and 45 h homework and self-studies

**Recommendation**
Basic physics background

**Literature**
J. Livingstone: Designing With Light: The Art, Science and Practice of Architectural Lighting Design, 2014

S. Russel: The Architecture Of Light: Interior Designer and Lighting Designer, 2012

M. Karlen: Lighting Design Basics, Indoor Lightin, 2004

R.H. Simons Lighting Engineering, 2001Simons, Lighting Engineering: Applied Calculations, 2001

R. Winchip, Fundamentals of Lighting, 2nd Edition, 2011

## 6.23 Module: Machine Vision [M-MACH-101923]

**Responsible:** Dr. Martin Lauer
Prof. Dr.-Ing. Christoph Stiller

**Organisation:** KIT Department of Mechanical Engineering

**Part of:** Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-MACH-105223 | Machine Vision | 6 CR | Lauer, Stiller |

**Competence Certificate**
Type of Examination: written exam

Duration of Examination: 60 Minutes

Modality of Exam: Written exam

**Prerequisites**
None.

**Competence Goal**
After having participated in th lecture the participants have gained knowledge on modern techniques of machine vision and pattern recognition which can be used to evaluatecamera images. This especially includes techniques in the areas of gray level image analysis, analysis of color images, segementation of images, describing the geometrical relationship between the image and the 3-dimensional world, and pattern recognition with various classification techniques. The participants have learned to analyze the algorithms mathematically, to implement them in software, and to apply them to tasks in video analysis. The participants are able to analyze real-world problems and to develop appropriate solutions.

**Content**
The lecture on machine vision covers basic techniques of machine vision. It focuses on the following topics:

image preprocessing

edge and corner detection

curve and parameter fitting

color processing

image segmentation

camera optics

pattern recognition

deep learning

Image preprocessing:

The chapter on image processing discusses techniques and algorithms to filter and enhance the image quality. Starting from an analysis of the typical phenomena of digital camera based image capturing the lecture introduces the Fourier transform and the Shannon-Nyquist sampling theorem. Furthermore, it introduces gray level histogram based techniques including high dynamic range imaging. The disussion of image convolution and typical filters for image enhancement concludes the chapter.

Edge and corner detection:

Gray level edges and gray level corners play an important role in machine vision since gray level edges often reveal valueable information about the boundaries and shape of objects. Gray level corners can be used as feature points since they can be identified easily in other images. This chapter introduces filters and algorithms to reveal gray level edges and gray level corners like the Canny edge detector and the Harris corner detector.

Curve and parameter fitting:

In order to describe an image by means of geometric primitives (e.g. lines, circles, ellipses) instead of just pixels robust curve and parameter fitting algorithms are necessary. The lecture introduces and discusses the Hough transform, total least sum of squares parameter fitting as well as robust alternatives (M-estimators, least trimmed sum of squares, RANSAC)

Color processing:

The short chapter on color processing discusses the role of color information in machine vision and introduces various models for color understanding and color representation. It concludes with the topic of color consistency.

Image Segmentation:

Image segmentation belongs to the core techniques of machine vision. The goal of image segmentation is to subdivide the image into several areas. Each area shares common properties, i.e. similar color, similar hatching, or similar semantic interpretation. Various ideas for image segmentation exist which can be used to create more or less complex algorithms. The lecture introduces the most important approaches ranging from the simpler algorithms like region growing, connected components labeling, and morphological operations up to highly flexible and powerful methods like level set approaches and random fields.

Camera optics:

The content of an image is related by the optics of the camera to the 3-dimensional world. In this chapter the lecture introduces optical models that describe the relationship between the world and the image including the pinhole camera model, the thin lens model, telecentric cameras, and catadioptric sensors. Furthermore, the lecture introduces camera calibration methods that can be used to determine the optical mapping of a real camera.

Pattern recognition:

Pattern recognition aims at recognizing semantic information in an image, i.e. not just analyzing gray values or colors of pixels but revealing which kind of object is shown by the pixels. This task goes beyond classical measurement theory and enters the large field of artificial intelligence. Rather than just being developped and optimized by a programmer, the algorithms are adapting themselves to their specific task using training algorithms that are based on large collections of sample images.

The chapter of pattern recognition introduces standard techniques of pattern recognition in the context of image understanding like the support vector machine (SVM), decision trees, ensemble and boosting techniques. It combines those classifiers with powerful feature representation techniques like the histogram of oriented gradients (HOG) features, locally binary patterns (LBP), and Haar features.

Deep learning:

Throughout recent years standard pattern recognition technqiues have more and more been outperformed by deep learning techniques. Deep learning is based on artificial neural networks, a very generic and powerful form of a classifier. The lecture introduces multi layer perceptrons as the most relevant form of artificial neural networks, discusses training algorithms and strategies to achieve powerful classifiers based on deep learning including deep auto encoders, convolutional networks, and multi task learning, among others.

**Workload**
total 180 h, hereof 60 h contact hours (45 h lecture, 15 h computer exersices), and 120 h homework and self-studies

**Recommendation**
Solid mathematical background.

**Learning type**
Lecture

**Literature**
Main results are summarized in the slides that are made available as pdf-files. Further recommendations will be presented in the lecture.

# M 6.24 Module: Measurement and Control Systems [M-MACH-101921]

**Responsible:** Prof. Dr.-Ing. Christoph Stiller
**Organisation:** KIT Department of Mechanical Engineering

**Part of:** Adjustment Courses (Modern Physics / Measurement and Control Systems)

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Each winter term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-MACH-103622 | Measurement and Control Systems | 6 CR | Stiller |

**Competence Certificate**
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.

**Prerequisites**
None

**Competence Goal**
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

**Workload**
total 180 h, hereof 60 h contac hours (45 h lecture, 15 h problem class), and 120 h homework and self-studies, an additional tutorial is offered

**Recommendation**
Solid mathematical background.

**Literature**
C. Stiller: Measurement and Control, scriptum

R. Dorf and R. Bishop: Modern Control Systems, Addison-Wesley

C. Phillips and R. Harbor: Feedback Control Systems, Prentice-Hall

# M 6.25 Module: Modern Physics [M-PHYS-101931]

**Responsible:** apl. Prof. Dr. Bernd Pilawa
**Organisation:** KIT Department of Physics
**Part of:** Adjustment Courses (Modern Physics / Measurement and Control Systems)

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-103629 | Modern Physics | 6 CR | Pilawa |

**Competence Certificate**
Type of Examination: written exam

Duration of Examination: 180 Minutes

Modality of Exam: The written exam is scheduled in the beginning of each semester.

**Prerequisites**
None

**Competence Goal**
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

**Workload**
total 180 h, hereof 75 h contact hours (60 h lecture, 15 h problem class), and 105 h homework and self-studies

**Recommendation**
Solid mathematical background, basic knowledge in physics

**Literature**
Paul A. Tipler: Physics for engineers and scientists
Paul A. Tipler: Modern Physics

## M 6.26 Module: Module Master's Thesis [M-ETIT-102362]

**Responsible:** Prof. Dr. Cornelius Neumann
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Master's Thesis

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 30 | Grade to a tenth | Each term | 1 term | English | 5 | 5 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-104732 | Master's Thesis | 30 CR | Neumann |

**Competence Certificate**
Written thesis and a presentation.

**Prerequisites**
Prerequisited for the registration of the msater's thesis are regulated in §14 (1) of the study and examination regulations. 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 O&P labs and the seminar course before starting the master's thesis.

The master's thesis can be registered at any time once the prerequisites are fulfilled.

**Modeled Conditions**
The following conditions have to be fulfilled:

1. The field Optics & Photonics Lab must have been passed.
2. The field Seminar Course (Research Topics in Optics & Photonics) must have been passed.

**Competence Goal**
Objective of the Masther's Thesis is to introduce students to in depth scientific working methods. They learn to analyze 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.

**Content**
According to §14 of the study and examination regulations, the master thesis should show that students are able to work independently and in a limited time on a problem from the field of study (Optics & Photonics) according to scientific methods. Students shall be given the opportunitiy to make suggestions for the topic. In exceptional cases, the chairperson of the examinations board will, at the request of the student, ensure that the student receives a topic for the Master's thesis within four weeks. In this case, the topic will be issued by the chairman of the examination board. Further details are regulated by §14 of the study and examination regulations.

**Module grade calculation**
The thesis will be graded by the Examiner. The grade should be given not later than 8 weeks
after the submission.

**Annotation**
You can find information regarding the registration of the Master's Thesis on ILIAS (course: KSOP Master).

**Workload**
900 h including writing of thesis, preparation and presentation of the final presentation.

# M 6.27 Module: Molecular Spectroscopy [M-CHEMBIO-101902]

**Responsible:** Prof. Dr. Manfred Kappes
apl. Prof. Dr. Andreas-Neil Unterreiner

**Organisation:** KIT Department of Chemistry and Biosciences

**Part of:** Specialization / Specialization - Quantum Optics & Spectroscopy
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Once | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-CHEMBIO-101864 | Molecular Spectroscopy | 4 CR | |

**Competence Certificate**
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.

**Prerequisites**
One page of exercises is handed out to the students as homework each week. Solutions to these exercices 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 suppported and encouraged (though not a formal requirement)

**Competence Goal**
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; asymmetric 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

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies

**Recommendation**
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

# 6.28 Module: Nano-Optics [M-PHYS-102146]

**Responsible:** PD Dr. Andreas Naber
**Organisation:** KIT Department of Physics
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Biomedical Photonics (Compulsory Elective Modules)
Specialization / Specialization - Solar Energy (Compulsory Elective Modules)
Specialization / Specialization - Quantum Optics & Spectroscopy
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Each winter term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-102282 | Nano-Optics | 6 CR | Naber |

**Competence Certificate**
Type of Examination: Oral exam

Duration of Examination: approx. 30 minutes

Modality of Exam: oral exam

**Prerequisites**
None

**Competence Goal**
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).

**Workload**
total 180 h, hereof 60 h contact hours (45 h lecture, 15 h problems class) and 120 h homework and self-studies

**Recommendation**
Solid mathematical background, basics of classical optics.

**Literature**
Will be mentioned in the lecture.

# M 6.29 Module: Nonlinear Optics [M-ETIT-100430]

**Responsible:** Prof. Dr.-Ing. Christian Koos
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Advanced Optics & Photonics – Theory and Materials

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each summer term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-101906 | Nonlinear Optics | 4 CR | Koos |

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 30 Minutes

Modality of Exam: The oral exam is offered continuously upon individual appointment.

**Prerequisites**
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.

**Competence Goal**
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

**Module grade calculation**
The module grade is the grade of the oral exam.

There is 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.

**Workload**
Approx. 180 h – 30 h lectures, 30 h exercises, 120 h homework and self-studies

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

**Literature**

R. Boyd. Nonlinear Optics. Academic Press, New York, 1992.
E.H. Li S. Chiang Y. Guo, C.K. Kao. Nonlinear Photonics. Springer Verlag, 2002
G. Agrawal, Nonlinear Fiber Optics, Academic Press, San Diego, 1995.

## 6.30 Module: Optical Engineering [M-ETIT-100456]

**Responsible:** Prof. Dr. Wilhelm Stork
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Engineering Optics & Photonics

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-100676 | Optical Engineering | 4 CR | Stork |

**Competence Certificate**
Achievement will be examined in an oral examination (approx. 20 minutes).

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

**Competence Goal**
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.

**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)

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and selfstudies

**Recommendation**
Solid mathematical background.

**Literature**

E. Hecht: Optics

J.W. Goodmann: Introduction to Fourier optics

K.K. Sharma: Optics - Principles and Applications

## 6.31 Module: Optical Networks and Systems [M-ETIT-103270]

**Responsible:** Prof. Dr.-Ing. Sebastian Randel
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-106506 | Optical Networks and Systems | 4 CR | Randel |

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: 20 min (approx.)

Modality of Exam: Oral exams (approx. 20 minutes) are offered throughout the year upon individual appointment.

**Prerequisites**
There are no prerequisites for participating in the examination.

**Competence Goal**
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 neetworks: 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 automotion: polymer-optical fiber (POF), MOST Bus, Profibus and Profinet, optical vs. electrical communication links, overcoming bandwidth limitations using digital signal processing.

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
total 120 h, hereof 30 h lecture, 15 h problems class and 75 h recapitulation and self-studies

**Recommendation**
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

## M 6.32 Module: Optical Systems in Medicine and Life Science [M-ETIT-103252]

**Responsible:** Prof. Dr. Werner Nahm
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Biomedical Photonics (Compulsory Elective Modules)
Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each summer term | 1 term | English | 4 | 5 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-106462 | Optical Systems in Medicine and Life Science | 3 CR | Nahm |

**Competence Certificate**
Written exam (60 minutes)

**Prerequisites**
none

**Competence Goal**
**Overall Course Objectives:**

This course will allow the students to understand how the basic optical and optoelectronic principles are applied in the design of modern medical devices and routine diagnostic equipment. Besides extending and deepening their expert knowledge in engineering sciences and physics this course will provide profound insight into the applicative, the regulatory and safety and the cost requirements. This will help to be able to understand how the systems are designed to fulfill the requirements.

Furthermore, in this course the students will be introduced into case-based learning. The in-class journal club helps to make the students become more familiar with the advanced literature in the field of study. This interactive format helps to improve the students' skills of understanding and debating current topics of active interest.

**Teaching Targets:**

The successful participation in this course enables the students to

- derive and formulate system requirements
- layout the system architecture of optical devices
- explain the underlying physical and physiological principles and mechanisms
- elaborate technical and methodological constraints and limitations

present, challenge and debate recent research results

**Content**
Optical Systems:

- Surgical microscope
- Scanning laser ophthalmoscope (SLO) / Confocal endomicroscope (CEM)
- Optical coherence tomography (OCT) / Optical biometer
- Refractive surgical laser
- Flow-Cytometry

Applied Optical Technologies:

- Magnification and illumination
- Fluorescence and diffuse reflectance imaging
- Confocal laser microscopy
- Low coherence interferometry
- fs-Laser
- Laser scattering (Mie-Therory)

Systems Design and Engineering:

- System architecture

V-Model of Product Development Process

**Module grade calculation**
The module grade is the grade of the written exam.

**Annotation**
Language English

**Workload**
Each credit point corresponds approximately to 30h of the student's workload. Here, the average student is expected to reach an average performance. This contains:

1. Presence during lectures (15 x 1.5 = 22.5h)
2. Preparation and wrap-up of subject matter (57.5h)

Preparation and presentation of one contribution to the in-class journal club (1 x 10h)

**Recommendation**
Good understanding of optics and optoelectronics.

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

# M 6.33 Module: Optical Transmitters and Receivers [M-ETIT-100436]

**Responsible:** Prof. Dr. Wolfgang Freude
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Each winter term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-100639 | Optical Transmitters and Receivers | 6 CR | Freude |

**Competence Certificate**
Oral examination (approx. 20 minutes). The individual dates for the oral examination are offered regularly.

**Prerequisites**
none

**Competence Goal**
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

**Module grade calculation**
The module grade is the grade of the oral exam.

**Workload**
Approx. 120 hours workload for the student. The amount of work is included:

30 h - Attendance times in lectures
15 h - Exercises
75 h - Preparation / revision phase

**Recommendation**
Knowledge of the physics of the pn-junction

**Literature**
Detailed textbook-style lecture notes can be downloaded from the IPQ lecture pages.
Grau, G.; Freude, W.: Optische Nachrichtentechnik, 3. Ed. Berlin: Springer-Verlag 1991. 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: Systems and Networks', 6th Ed. Elsevier (Imprint: Academic Press), Amsterdam 2013

## 6.34 Module: Optical Waveguides and Fibers [M-ETIT-100506]

**Responsible:** Prof. Dr.-Ing. Christian Koos
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-101945 | Optical Waveguides and Fibers | 4 CR | Koos |

**Competence Certificate**
Type of Examination: Oral exam

Duration of Examination: approx. 20 minutes

Modality of Exam: The written exam is offered continuously upon individual appointment.

**Prerequisites**
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.

**Competence Goal**
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 relatons, multimode interference couplers and directional couplers, waveguide gratings, material gain and absorption in optical waveguides, bent waveguides

**Module grade calculation**
The module grade is the grade of the oral exam.

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.

**Workload**
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial) and 75 h homework and self-studies.

**Recommendation**
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

# M 6.35 Module: Optics and Photonics Lab [M-PHYS-102189]

**Responsible:** PD Dr. Michael Hetterich
**Organisation:** KIT Department of Physics
**Part of:** Optics & Photonics Lab

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 10 | pass/fail | Each term | 2 terms | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-104511 | Optics and Photonics Lab | 10 CR | Hetterich |

**Competence Certificate**
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 tobias.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 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.

**Prerequisites**
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.

**Competence Goal**
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.

**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

**Recommendation**
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.

## M 6.36 Module: Optics and Vision in Biology [M-CHEMBIO-101906]

**Responsible:** Prof. Dr. Martin Bastmeyer
**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** Specialization / Specialization - Biomedical Photonics (Compulsory Elective Modules)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-CHEMBIO-105198 | Optics and Vision in Biology | 4 CR | Bastmeyer |

**Competence Certificate**
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.

**Prerequisites**
none

**Competence Goal**
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 relex and gaze control
• concieve 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

**Workload**
Total 120 h, hereof 40 h contact hours and 80 h homework and self-studies.

**Recommendation**
Passed exam of the Adjustment Course in "Basic Molecular Cell Biology" AdjC-BMCB.

Attendance to the lecture.

**Learning type**
Lecture

**Literature**
ecture presentations are provided in pdf-format
Neuroscience, Purves, D. et al., Sinauer, 2011
Biology, Campbell NA and Reece JB, Prentice Hall International, 2011

## 6.37 Module: Optoelectronic Components [M-ETIT-100509]

**Responsible:** Prof. Dr.-Ing. Sebastian Randel
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Advanced Optics & Photonics – Methods and Components

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each summer term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-101907 | Optoelectronic Components | 4 CR | Randel |

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 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.

**Prerequisites**
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.

**Competence Goal**
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´sesitivity 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

**Module grade calculation**
The module grade is the grade of the oral exam.

**Annotation**
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.

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies

**Recommendation**
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.

Agrawal, G.P.: Lightwave technology. Hoboken: John Wiley & Sons 2004

Iizuka, K.: Elements of photonics. Vol. I, especially Vol. II. Hoboken: John Wiley & Sons 2002

Further textbooks in German (also in electronic form) can be named on request.

# 6.38 Module: Organic Photochemistry [M-CHEMBIO-101907]

**Responsible:** Prof. Dr. Hans-Achim Wagenknecht
**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** Specialization / Specialization - Biomedical Photonics (Compulsory Elective Modules)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-CHEMBIO-105195 | Organic Photochemistry | 3 CR | |

**Competence Certificate**
Type of Examination: Oral exam

Duration of Examination: approx. 30 min

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

**Competence Goal**
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

**Workload**
total 90 h, hereof 30 h contact hours (lecture) and 60 h recapitulation and self-studies

**Recommendation**
Solid background in organic chemistry.

**Literature**
B. König (ed.), Chemical Photocatalysis, De Gruyter, Berlin, 2013.
A. Albini, M. Fagnoni (Hrsg.), Handbook of Synthetic Photochemistry, Wiley-VCH, Weinheim, 2010.
P. Klán, J. Wirz, Photochemistry of Organic Compounds, Wiley, 2009.
N. J. Turro, V. Ramamurthy, J. C. Scaiano, Principles of Molecular Photochemistry, University Science Books, 2009.

# M 6.39 Module: Photonic Integrated Circuit Design and Applications [M-ETIT-105914]

**Responsible:** Prof. Dr.-Ing. Christian Koos
Prof. Dr.-Ing. Sebastian Randel

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Specialization / Specialization - Photonic Materials and Devices (Usage from 4/1/2022)
Specialization / Specialization - Optical Systems (Usage from 4/1/2022)
Specialization / Specialization - Quantum Optics & Spectroscopy (Usage from 4/1/2022)
Additional Achievements (Usage from 4/1/2022)

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Each summer term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-111896 | Photonic Integrated Circuit Design and Applications | 6 CR | |

**Competence Certificate**

- Part 1 – Solutions of problem sets: We will grade your solutions of the various problem sets and design projects. To this end, please upload your solution via the online teaching platform of your respective institution (see above) before the respective deadline. Please merge all pages into a single pdf file, and please use a scanner. Smartphone made snapshots are often illegible, and in this case your solutions cannot not be evaluated. In case there are any technical difficulties with the platforms, you may also submit your solutions by e-mail to picda@ipq.kit.edu before the respective deadline.
- Part 2 - Presentation of one pre-assigned problem set: At the beginning of the term, design projects will be pre-assigned to groups of participants. Each of these groups will explain their approach and results to lecturers and peer students in a short presentation (approx. 15 min), followed by approx. 10 min of public discussion with peer students and professors, and an individual private interview of each group member (approx. 10 min per person).

The overall impression is rated.

**Competence Goal**
The students understand the basic principles of photonic component design and can apply them to concrete design tasks of increasing complexity and independence, that they will solve in small groups and present to their peers. Doing so they will learn to translate theoretical knowledge gained during the lecture into actionable knowledge used to solve hands-on design tasks. In addition to design principles, students will learn how to satisfy key requirements for making photonic integrated circuits manufacturable and useable in a system environment, such as corner analysis of manufacturing tolerances, design for testability, design for manufacturability, and packaging. In short, we aim at teaching students the skills for hands-on design of manufacturable and application relevant photonic integrated circuits, preparing them to productively contribute to a design team. In addition, we will convey the most recent trends in the application of photonic integrated circuits and let students design a circuit addressing one of these application spaces, giving them a feeling for both the potential as well as the limitations of the technology, so that they may take informed decisions on what systems to integrate in the future.

**Content**
**Lectures:**

- Lecture 1: Introduction to silicon photonics
- Lecture 2: Silicon photonics – technology overview
- Lecture 3: Wave propagation in silicon photonic waveguides
- Lecture 4: Mode expansion and orthogonality
- Lecture 5: Coupled-mode theory
- Lecture 6: Selected passive devices
- Lecture 7: Modulators
- Lecture 8: Photodetectors
- Lecture 9: Optical amplifiers and lasers
- Lecture 10: Test and packaging
- Lecture 11: Optical communications
- Lecture 12: Optical metrology
- Lecture 13: Biophotonics and neurophotonics
- Lecture 14: Integrated quantum optics and optical computing

**Design lab:**

- Problem Set 1: Mode fields and mode expansion
- Problem Set 2: Coupling efficiency and coupled-mode theory
- Design Project A: Optical filter
- Design Project B: Optical transceiver
- Design Project C: Optical communication link

**Module grade calculation**
The module grade results of the assessment of the solutions of the design projects and problem sets, the presentation of one design project with discussion, and the individual oral interview.

Details will be given during the lecture.

**Workload**
Each credit point corresponds to approximately 30 hours of work (of the students). This is based on average students who achieve an average performance. The workload includes (e.g. 2 SWS):

1. attendance in lectures an exercises: 15*2 h = 30 h
2. preparation / follow-up: 15*2 h = 30 h
3. preparation of and attendance in examination: 120 h

A total of 180 h = 6 CR

**Learning type**
In addition to the teaching of fundamental concepts to the extent necessary to enable students to perform practical designs, the lecture will focus from the start on a specific technology platform (silicon-on-insulator) in which the students will solve design problems of increasing complexity with the design suite Lumerical. As the final hands-on problem, students will design an entire photonic subsystem for an application of their choice, leaving free room for creative thinking and self-driven work. Since each group of students will present one of the solved designed problems to their peers, students will get exposed to solutions found for and practical problems encountered in a variety of design tasks, providing them with a wider experience base to draw on for future design.

Since the class will be taught by lecturers from several Universities, all lectures will be streamed live (with the possibility to interact and to ask questions) and made available online. Design tasks will be performed with the Design Suite Lumerical, for which introductory videos will be made available. An online forum will be provided to allow students to ask questions offline to the lecturers as well as to interact with each other, inside and across Universities.

## 6.40 Module: Plastic Electronics / Polymerelectronics [M-ETIT-100475]

**Responsible:** Prof. Dr. Gerardo Hernandez Sosa
Prof. Dr. Ulrich Lemmer

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Specialization / Specialization - Solar Energy (Compulsory Elective Modules)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each winter term | 1 term | German/English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-100763 | Plastic Electronics / Polymerelectronics | 3 CR | Lemmer |

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 20 min

Modality of Exam: Oral exam (approx. 20 minutes)

**Prerequisites**
none

**Competence Goal**
The students

- understand the electronic and optical characteristics of organic semiconductors
- know the fundamental differences between organic and conventional inorganic semiconductors.
- have basic knowledge of manufacturing and processing technologies,
- have knowledge of organic light-emitting diodes, organic solar cells and photodiodes, organic field-effect transistors and organic lasers.
- have an overview of the possible applications, markets and development lines for these components.
- are able to work in multidisciplinary teams with engineers, chemists and physicists

**Content**

1. Introduction
2. Optoelectronic properties of organic semiconductors
3. Organic light emitting diodes (OLEDs
4. Applications in Lighting and Displays
5. Organic FETs
6. Organic photodetectors and solar cells
7. Lasers and integrated optics

**Module grade calculation**
The module grade is the grade of the oral exam.

**Annotation**
Lecture and excersises are held as required in German or English.

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

**Recommendation**
Knowledge of semiconductor components.

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

## M 6.41 Module: Quantum Optics [M-PHYS-103093]

**Responsible:** Prof. Dr. Anja Metelmann
Prof. Dr. Carsten Rockstuhl

**Organisation:** KIT Department of Physics

**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Specialization / Specialization - Quantum Optics & Spectroscopy
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-106135 | Quantum Optics | 4 CR | Metelmann, Rockstuhl |

**Competence Certificate**
Type of Examination: oral examination (or written)

Duration of Examination: approx. 30 minutes (oral) (or 90 minutes (written))

Modality of Exam: There will be an oral examination or a written one, depending on the number of participants. This will be settled after the end of the fourth lecture. The oral examination will last for approx. 30 minutes. The written examination lasts for 90 minutes and shall be written without any supporting documents.

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

**Competence Goal**
The students of quantum optics comprehend the physics of quantum optical phenomena, the necessary theoretical means for their description, and the application of quantum optical resources in different applications and technologies. They learn how to express quantum optical phenomena in a mathematical language and can apply routinely different techniques to study quantum optical phenomena in specific situations. They are trained to solve basic problems in quantum optics.

The students

- learn about the quantisation of electromagnetic fields,
- understands the details of different quantum states of light,
- get an overview over experiments that were important in the development of quantum optics,
- develop an understanding for the quantum optical description of the first and second order coherence functions, and
- understand and can routinely apply different means to describe the interaction of quantum states of light with quantum emitters.

**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.)

**Workload**
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial), and 75 h homework and self-studies

**Recommendation**
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*.
- P. Meystre and M. Sargent, *Elements of Quantum Optics*.
- W. Schleich, *Quantum Optics in Phase Space*.

# M 6.42 Module: Quantum Optics at the Nano Scale, with Exercises [M-PHYS-106508]

**Responsible:** Prof. Dr. David Hunger
**Organisation:** KIT Department of Physics
**Part of:** Specialization / Specialization - Quantum Optics & Spectroscopy (Usage from 4/1/2023)
Additional Achievements (Usage from 4/1/2023)

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 8 | Grade to a tenth | Irregular | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-113126 | Quantum Optics at the Nano Scale, with Exercises | 8 CR | Hunger |

**Competence Certificate**
Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**
none

**Modeled Conditions**
The following conditions have to be fulfilled:

1. The module M-PHYS-106510 - Quantum Optics at the Nano Scale, without Exercises must not have been started.

**Competence Goal**
Students gain knowledge about the fundamentals in the field of quantum- and nano optics and learn about basic concepts and examples of optical quantum systems. This is intended to enable participants to follow current research in the field. The Tutorial is designed as a journal club, where selected publications will be presented by students. Students learn how to become familiar with current research topics, how to interpret research results based on the concepts presented in the lecture, and how to present scientific results.

**Content**

- Fundamentals of quantized light fields and light-matter interactions
- Micro- and nanooptical devices
- Dipole emission in structured environments
- Solid state quantum emitters
- Optical readout of single spins
- Quantum communication
- Quantum networks
- Quantum sensing
- Quantum computing

**Workload**
240 hours consisting of attendance time (60 hours), wrap-up of the lecture incl. exam preparation and preparation of the exercises (180 hours).

**Recommendation**
Basic knowledge in classical electromagnetism and optics, quantum mechanics, atomic physics; quantum optics is beneficial but not mandatory

**Literature**

- Principles of Nano-Optics, Novotny, Hecht, Cambridge University Press
- Quantum Optics, M. Scully, M. Suhail Zubairy, Cambridge University Press
- Fundamentals of Photonics, Saleh,Teich
- research articles (will be sent around)

## M 6.43 Module: Quantum Optics at the Nano Scale, without Exercises [M-PHYS-106510]

**Responsible:** Prof. Dr. David Hunger
**Organisation:** KIT Department of Electrical Engineering and Information Technology
KIT Department of Physics
**Part of:** Specialization / Specialization - Quantum Optics & Spectroscopy (Usage from 4/1/2023)
Additional Achievements (Usage from 4/1/2023)

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Irregular | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-113128 | Quantum Optics at the Nano Scale, without Exercises | 6 CR | Hunger |

### Competence Certificate
Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

### Prerequisites
none

### Modeled Conditions
The following conditions have to be fulfilled:

1. The module M-PHYS-106508 - Quantum Optics at the Nano Scale, with Exercises must not have been started.

### Competence Goal
Students gain knowledge about the fundamentals in the field of quantum- and nano optics and learn about basic concepts and examples of optical quantum systems. This is intended to enable participants to follow current research in the field.

### Content

- Fundamentals of quantized light fields and light-matter interactions
- Micro- and nanooptical devices
- Dipole emission in structured environments
- Solid state quantum emitters
- Optical readout of single spins
- Quantum communication
- Quantum networks
- Quantum sensing
- Quantum computing

### Workload
180 hours consisting of attendance time (45 hours), wrap-up of lecture incl. exam preparation (135 hours).

### Recommendation
Basic knowledge in classical electromagnetism and optics, quantum mechanics, atomic physics; quantum optics is beneficial but not mandatory

### Literature

- Principles of Nano-Optics, Novotny, Hecht, Cambridge University Press
- Quantum Optics, M. Scully, M. Suhail Zubairy, Cambridge University Press
- Fundamentals of Photonics, Saleh,Teich
- research articles (will be sent around)

# 6.44 Module: Research Project [M-PHYS-102194]

**Responsible:** Prof. Dr. Carsten Rockstuhl
**Organisation:** KIT Department of Physics
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Biomedical Photonics (Compulsory Elective Modules)
Specialization / Specialization - Optical Systems
Specialization / Specialization - Solar Energy (Compulsory Elective Modules)
Specialization / Specialization - Quantum Optics & Spectroscopy
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-103632 | Research Project | 4 CR | Rockstuhl |

**Competence Certificate**
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.

**Prerequisites**
None.

**Competence Goal**
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.

**Workload**
total 120 h, hereof 60 h contact hours (supervised research) and 60 h preparation of report and self-studies

**Recommendation**
Basic background in optics and photonics.

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

# M 6.45 Module: Seminar Course [M-PHYS-102195]

**Responsible:** Prof. Dr. David Hunger
**Organisation:** KIT Department of Physics
**Part of:** Seminar Course (Research Topics in Optics & Photonics)

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | pass/fail | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-104516 | Seminar Course | 4 CR | Hunger |

**Competence Certificate**
Type of Examination: study achivement

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.

**Prerequisites**
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.

**Competence Goal**
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.

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

**Recommendation**
Basic background in optics and photonics.

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

# M 6.46 Module: Solar Energy [M-ETIT-100524]

**Responsible:** Prof. Dr. Bryce Sydney Richards
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Solar Energy (Compulsory Modules)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Each winter term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-100774 | Solar Energy | 6 CR | Richards |

**Competence Certificate**
Type of Examination: written exam

Duration of Examination: 120 Minutes

Modality of Exam: One written exam at the end of each semester.

**Prerequisites**
Active participation in the lectures and problem classes.

**Competence Goal**
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**

**Module grade calculation**
The module grade is the grade of the written exam.

**Workload**
Total 180 h, herof 60 h contact hours (45 h lecture, 15 h problem class), and 120 h homework and self-studies

**Recommendation**
Semiconductor fundamentals

**Literature**

P. Würfel: Physics of Solar Cells

V. Quaschning: Renewable Energy Systems

C. Honsberg and S. Bowden, PV Education CD-ROM and website, http://www.pveducation.org/pvcdrom

## 6.47 Module: Solar Thermal Energy Systems [M-MACH-101924]

**Responsible:** apl. Prof. Dr. Ron Dagan
**Organisation:** KIT Department of Mechanical Engineering

**Part of:** Specialization / Specialization - Solar Energy (Compulsory Elective Modules)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each winter term | 1 term | English | 4 | 3 |

| Mandatory | | | |
|---|---|---|---|
| T-MACH-106493 | Solar Thermal Energy Systems | 3 CR | Dagan |

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 30 minutes

Modality of Exam: oral exam

**Prerequisites**
None

**Competence Goal**
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.

**Workload**
Total 90 h, hereof 30 h contact hours and 60 h homework and self-studies

**Learning type**
Lecture, tutorial

**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)

## M 6.48 Module: Solid-State Optics [M-PHYS-102408]

**Responsible:** PD Dr. Michael Hetterich
**Organisation:** KIT Department of Physics
**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Solar Energy (Compulsory Elective Modules)
Specialization / Specialization - Quantum Optics & Spectroscopy
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Each winter term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-104773 | Solid-State Optics, without Exercises | 6 CR | Hetterich |

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 45 minutes

Modality of Exam: Appointments for the oral exam can be made individually with the lecturer.

**Prerequisites**
none

**Competence Goal**
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
- are familiar with the classical Drude-Lorentz model and its implications for the optical properties of solids
- understand the relation between classical and quantum mechanical models for the dielectric function as well as the importance of the Kramers Kronig relations
- can explain near-band-edge optical spectra of semiconductors and insulators based on the concepts of joint density of states, oscillator strength, as well as excitonic effects
- are familiar with common experimental techniques of optical spectroscopy
- understand the origin of different optical nonlinearities and high-excitation effects as well as their mathematical description, their experimental realization and their applications
- comprehend the basics of group theory and can apply it to solid state optics

**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.

**Workload**
total 180 h, hereof 90 h contact hours (lectures), and 90 h recapitulation and self-studies

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

**Literature**

- H. Kalt, C. Klingshirn: Semiconductor Optics
- F. Wooten: Optical Properties of Solids
- P.K. Basu: Theory of optical processes in semiconductors
- H. Ibach and H. Lüth: Solid-State Physics

## M 6.49 Module: Spectroscopic Methods [M-CHEMBIO-101900]

**Responsible:** Prof. Dr. Manfred Kappes
apl. Prof. Dr. Andreas-Neil Unterreiner

**Organisation:** KIT Department of Chemistry and Biosciences

**Part of:** Advanced Optics & Photonics – Methods and Components

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Once | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-CHEMBIO-103590 | Spectroscopic Methods | 3 CR | |

**Competence Certificate**
Type of Examination: written exam

Duration of Examination: 120 Minutes

Modality of Exam: The written exam is sheduled 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.

**Prerequisites**
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).

**Competence Goal**
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.
The students
• 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
are introduced into linear and nonlinear molecular spectroscopy including two-dimensional techniques such as two-dimensional vibrational spectroscopy)

**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

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

**Recommendation**
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

# M 6.50 Module: Supplementary Studies on Science, Technology and Society [M-FORUM-106753]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**

**Part of:** Additional Achievements (Usage from 10/1/2024)

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 16 | Grade to a tenth | Each term | 3 terms | German | 3 | 1 |

**Election notes**
Students have to self-record the achievements obtained in the Supplementary Studies on Science, Technology and Society in their study plan. FORUM (formerly ZAK) records the achievements as "non-assigned" under "ÜQ/SQ-Leistungen". Further instructions on self-recording of achievements can be found in the FAQ at https://campus.studium.kit.edu/ and on the FORUM homepage at https://www.zak.kit.edu/english/16495.php. The title of the examination and the amount of credits override the modules placeholders.

If you want to use FORUM achievements for both your Interdisciplinary Qualifications and for the Supplementary Studies, please record them in the Interdisciplinary Qualifications first. You can then get in contact with the FORUM study services (stg@zak.kit.edu) to also record them in your Supplementary Studies.

In the Advanced Unit you can choose examinations from three subject areas: "About Knowledge and Science", "Science in Society" and "Science in Social Debates". It is advised to complete courses from each of the three subject areas in the Advanced Unit.

To self-record achievements in the Advanced Unit, you have to select a free placeholder partial examination first. The placeholders' title do *not* affect which achievements the placeholder can be used for!

| | | | |
|---|---|---|---|
| **Mandatory** | | | |
| T-FORUM-113578 | Lecture Series Supplementary Studies on Science, Technology and Society - Self Registration | 2 CR | Mielke, Myglas |
| T-FORUM-113579 | Basic Seminar Supplementary Studies on Science, Technology and Society - Self Registration | 2 CR | Mielke, Myglas |
| **Advanced Unit Supplementary Studies on Science, Technology and Society (Election: at least 12 credits)** | | | |
| T-FORUM-113580 | Elective Specialization Supplementary Studies on Science, Technology and Society / About Knowledge and Science - Self-Registration | 3 CR | Mielke, Myglas |
| T-FORUM-113581 | Elective Specialization Supplementary Studies on Science, Technology and Society / Science in Society - Self-Registration | 3 CR | Mielke, Myglas |
| T-FORUM-113582 | Elective Specialization Supplementary Studies on Science, Technology and Society / Science in Public Debates - Self Registration | 3 CR | Mielke, Myglas |
| **Mandatory** | | | |
| T-FORUM-113587 | Registration for Certificate Issuance - Supplementary Studies on Science, Technology and Society | 0 CR | Mielke, Myglas |

**Competence Certificate**
The monitoring is explained in the respective partial achievement.

They are composed of:
- Protocols
- Reflection reports
- Presentations
- Preparation of a project work
- An individual term paper
- An oral examination
- A written exam

Upon successful completion of the supplementary studies, graduates receive a graded report and a certificate issued by the FORUM.

**Prerequisites**

The course is offered during the course of study and does not have to be completed within a defined period. Enrollment is required for all assessments of the modules in the supplementary studies.

Participation in the supplementary studies is regulated by § 3 of the statutes. KIT students register for the supplementary studies by selecting this module in the student portal and booking a performance themselves. Registration for courses, assessments, and exams is regulated by § 8 of the statutes and is usually possible shortly before the start of the semester.

The course catalog, module description (module manual), statutes (study regulations), and guidelines for creating the various written performance requirements can be downloaded from the FORUM homepage at https://www.zak.kit.edu/begleitstudium-wtg.

**Competence Goal**

Graduates of the Supplementary Studies on Science, Technology, and Society gain a solid foundation in understanding the interplay between science, the public, business, and politics. They develop practical skills essential for careers in media, political consulting, or research management. The program prepares them to foster innovation, influence social processes, and engage in dialogue with political and societal entities. Participants are introduced to interdisciplinary perspectives, encompassing social sciences and humanities, to enhance their understanding of science, technology, and society. The teaching objectives of this supplementary degree program include equipping participants with both subject-specific knowledge and insights from epistemological, economic, social, cultural, and psychological perspectives on scientific knowledge and its application in various sectors. Students are trained to critically assess and balance the implications of their actions at the intersection of science and society. This training prepares them for roles as students, researchers, future decision-makers, and active members of society.

Through the program, participants learn to contextualize in-depth content within broader frameworks, independently analyze and evaluate selected course materials, and communicate their findings effectively in both written and oral formats. Graduates are adept at analyzing social issues and problem areas, reflecting on them critically from a socially responsible and sustainable standpoint.

**Content**
The Supplementary Studies on Science, Technology and Society can be started in the 1st semester of the enrolled degree programme and is not limited in time. The wide range of courses offered by FORUM makes it possible to complete the program usually within three semesters. The supplementary studies comprises 16 or more credit points (LP). It consists of two modules: the Basic Module (4 LP) and the Advanced Module (12 LP).

The Advanced Module is divided into 3 thematic subject areas:

**Subject area 1: About Knowledge and Science**

This is about the internal perspective of science: students explore the creation of knowledge, distinguishing between scientific and non-scientific statements (e.g., beliefs, pseudo-scientific claims, ideological statements), and examining the prerequisites, goals, and methods of knowledge generation. They investigate how researchers address their own biases, analyze the structure of scientific explanatory and forecasting models in various disciplines, and learn about the mechanisms of scientific quality assurance.

After completing courses in the "Knowledge and Science" area, students can critically reflect on the ideals and realities of contemporary science. They will be able to address questions such as: How robust is scientific knowledge? What are the capabilities and limitations of predictive models? How effective is quality assurance in science, and how can it be improved? What types of questions can science answer, and what questions remain beyond its scope?

**Subject area 2: Science in Society**

This focuses on the interactions between science and different areas of society, such as how scientific knowledge influences social decision-making and how social demands impact scientific research. Students learn about the specific functional logics of various societal sectors and, based on this understanding, estimate where conflicts of goals and actions might arise in transfer processes—for example, between science and business, science and politics, or science and journalism. Typical questions in this subject area include: How and under what conditions does an innovation emerge from a scientific discovery? How does scientific policy advice work? How do business and politics influence science, and when is this problematic? According to which criteria do journalists incorporate scientific findings into media reporting? Where does hostility towards science originate, and how can social trust in science be strengthened?

After completing courses in the "Sciene in Society" area, students can understand and assess the goals and constraints of actors in different societal sectors. This equips them to adopt various perspectives of communication and action partners in transfer processes and to act competently at various social interfaces with research in their professional lives.

**Subject area 3: Science in Public Debates**

The courses in this subject area provide insights into current debates on major social issues such as sustainability, digitalization, artificial intelligence, gender equality, social justice, and educational opportunities. Public debates on complex challenges are often polarized, leading to oversimplifications, defamation, or ideological thinking. This can hinder effective social solution-finding processes and alienate people from the political process and from science. Debates about sustainable development are particularly affected, as they involve a wide range of scientific and technological knowledge in both problem diagnosis (e.g., loss of biodiversity, climate change, resource consumption) and solution development (e.g., nature conservation, CCS, circular economy).

By attending courses in "Science in Public Debates," students are trained in an application-oriented way to engage in factual debates—exchanging arguments, addressing their own prejudices, and handling contradictory information. They learn that factual debates can often be conducted more deeply and with more nuance than is often seen in public discourse. This training enables them to handle specific factual issues in their professional lives independently of their own biases and to be open to differentiated, fact-rich arguments.

**Module grade calculation**
The overall grade of the supplementary course is calculated as a credit-weighted average of the grades that were achieved in the advanced module.

**Annotation**
Climate change, biodiversity crisis, antibiotic resistance, artificial intelligence, carbon capture and storage, and gene editing are just a few areas where science and technology can diagnose and address numerous social and global challenges. The extent to which scientific findings are considered in politics and society depends on various factors, such as public understanding and trust, perceived opportunities and risks, and ethical, social, or legal considerations.
To enable students to use their expertise as future decision-makers in solving social and global challenges, we aim to equip them with the skills to navigate the interfaces between science, business, and politics competently and reflectively. In the Supplementary Studies, they acquire foundational knowledge about the interactions between science, technology, and society.

They learn:
- How reliable scientific knowledge is produced,
- how social expectations and demands influence scientific research, and
- how scientific knowledge is adopted, discussed, and utilized by society.

The program integrates essential insights from psychology, philosophy, economics, social sciences, and cultural studies into these topics. After completing the supplementary studies programme, students can place the content of their specialized studies within a broader social context. This prepares them, as future decision-makers, to navigate competently and reflectively at the intersections between science and various sectors of society, such as politics, business, or journalism, and to contribute effectively to innovation processes, public debates, or political decision-making.

Additional credit points (supplementary achievements), up to a maximum of 12, can be earned from interdisciplinary achievements and can be included in the supplementary course. Upon request, these supplementary achievements are listed in the certificate of the accompanying course, marked as such, and recorded with their grades as specified in paragraph 9. However, these supplementary achievements are **not** included in the calculation of the overall grade for the accompanying course.
The statutes for the accompanying study programme Science, Technology and Society apply.

**Workload**
The workload is made up of the number of hours of the individual modules:

- Basic Module approx. 120 hours
- Advanced Module approx. 390 hours

> Total: approx. 510 hours

In the form of supplementary services, up to approximately 390 hours of work can be added.

**Recommendation**
It is recommended to complete the supplementary study program in three or more semesters, beginning with the lecture series on science, technology, and society in the summer semester. Alternatively, you can start with the basic seminar in the winter semester and then attend the lecture series in the summer semester.

Courses in the Advanced Module can be taken simultaneously. It is also advised to complete courses from each of the three subject areas in the advanced unit.

**Learning type**
- Lectures
- Seminars/Project Seminars
- Workshops

# M 6.51 Module: Systems and Software Engineering [M-ETIT-100537]

**Responsible:** Prof. Dr.-Ing. Eric Sax
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each winter term | 1 term | English | 4 | 2 |

| Mandatory | | | |
|---|---|---|---|
| T-ETIT-100675 | Systems and Software Engineering | 4 CR | Sax |

**Competence Certificate**
Written exam, approximately 90 minutes.

Students are given the opportunity to earn a grade bonus through separate task assignments. If the grade of the written exam is between 4.0 and 1.3, the bonus improves the grade by a maximum of one grade level (0.3 or 0.4). The exact criteria for awarding a bonus will be announced at the beginning of the lecture. Bonus points do not expire and remain valid for exams taken at a later date.

**Prerequisites**
none

**Competence Goal**
• Students are able to analyse and explain the functional principles and applications of embedded systems.

• Students are able to evaluate and apply maturity models as well as Software Development Life Cycle models including the waterfall model, V-model, prototyping model, agile models, and DevOps.

• Students are able to apply various creativity techniques to develop innovative solutions to problems. They will be able to derive and analyse requirements.

• Students are familiar with diagram formats software modelling languages; they can evaluate and create these based on problem descriptions of an application area. They will be able to create and evaluate functional, data-oriented, algorithmic, state-oriented, and object-oriented views.

• Students are able to understand and apply various aspects of the realization of embedded systems. They will be able to consider implementation alternatives: hardware, co-design and scheduling aspects.

• Students are familiar with the various testing phases in a project and can explain them. They can assess the reliability of a system and understand the concept of functional safety.

**Content**
The focus of the course is on processes and methods for the design of systems composed of electrical, electronic and electronically programmable systems that contain software, hardware and mechanical components. The desired competencies of the course include the knowledge and goal-oriented use of modeling techniques, design processes, description and representation tools as well as specification languages that correspond to the current state of the art.

**Module grade calculation**
The grade is determined by the written exam and the bonus points.

**Workload**
Total 120 h, hereof 45 h contact hours (30 h lecture, 15 h tutorial) and 75 h homework and self-studies

**Recommendation**
Knowledge in Digital Technology and Information and Automation Technology (e.g. module M-ETIT-102102 and M-ETIT-106336)

# M 6.52 Module: Theoretical Nanooptics [M-PHYS-102295]

**Responsible:** Prof. Dr. Markus Garst
Prof. Dr. Carsten Rockstuhl

**Organisation:** KIT Department of Physics

**Part of:** Specialization / Specialization - Photonic Materials and Devices (Usage from 10/1/2019)
Specialization / Specialization - Optical Systems (Usage from 10/1/2019)
Specialization / Specialization - Solar Energy (Compulsory Elective Modules) (Usage from 10/1/2019)
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 6 | Grade to a tenth | Irregular | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-104587 | Theoretical Nanooptics | 6 CR | Garst, Rockstuhl |

**Competence Certificate**
Oral Exam. In the MSc Physics, this module is examined together with further modules attended as part of the major in physics. The total duration of the oral exam is approx. 60 minutes.

**Prerequisites**
none

**Competence Goal**
The properties of light at the nanoscale can be controlled by various means. The aim of this lecture is to familiarize the students with the different possibilities that rely on nanostructured dielectric or metallic materials and to outline on solid mathematical grounds the analytical description of observable effects. The lecture is meant as a complementary source of education to experimental lecture. It shall provide the students with the necessary skills to work themselves in the field of theoretical nanooptics.

**Content**

- Dispersion relation to describe light in extended systems such as free space, interfaces, planar waveguides and waveguides with complicated geometrical cross sections.
- Description of the interaction of light with isolated objects such as spheres, cylinders, ellipsoids and prolates and oblates.
- Properties of plasmonic nanoparticles and the ability to tune their properties
- Notion of optical antennas and the discussion of their basic characteristics
- Description of the dynamics of wave propagation by perturbed eigenstates, i.e. coupled mode theory. Application to optical waveguide arrays.
- Discussion of metamaterials (unit cells, homogenization, light propagation, applications)
- Transformation optics
- Analytical modeling and phenomenological tools to describe nanooptical systems

**Workload**
180 hours composed of active time (45), wrap-up of the lecture incl. preparation of the examination and the excercises (135)

**Recommendation**
Solid mathematical background, good knowledge of classical electromagnetism and theoretical optics.

**Literature**

- L. Novotny and B. Hecht, Principle of Nano-Optics, Cambridge
- S. A. Maier, Plasmonics, Springer
- J. D. Joannopoulos, S. G. Johnson, J. N. Winn and R. D. Meade, Photonic Crystals: Molding the Flow of Light, University Press

# 6.53 Module: Theoretical Optics [M-PHYS-102280]

**Responsible:** PD Dr. Boris Narozhnyy
Prof. Dr. Carsten Rockstuhl

**Organisation:** KIT Department of Physics

**Part of:** Advanced Optics & Photonics – Theory and Materials

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 4 | Grade to a tenth | Each summer term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-PHYS-102305 | Theoretical Optics - Unit | 0 CR | Narozhnyy, Rockstuhl |
| T-PHYS-102278 | Theoretical Optics | 4 CR | Narozhnyy, Rockstuhl |

### Competence Certificate
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.

### Prerequisites
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 exercices and the test exam (the test exam is counted equivalent to three problems sheets) have to be solved correctly.

### Competence Goal
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)
- Diffraction Theory (The Principles of Huygens and Fresnel, Scalar Diffraction Theory: Green's Function, Helmholtz-Kirchhoff Theorem, Kirchhoff Formulation of Diffraction, Fresnel-Kirchhoff Diffraction Formula, Rayleigh-Sommerfeld Formulation of Diffraction, Angular Spectrum Method, Fresnel and Fraunhofer Diffraction, Method of Stationary Phases, Basics og Holography)
- 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)

### Workload
total 120 h, hereof 45 h contact hours (30 h lecture, 15 h problem class), and 75 h homework and self-studies

### Recommendation
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

# 6.54 Module: X-Ray Optics [M-MACH-101920]

**Responsible:** Dr. Arndt Last
**Organisation:** KIT Department of Mechanical Engineering

**Part of:** Specialization / Specialization - Photonic Materials and Devices
Specialization / Specialization - Optical Systems
Additional Achievements

| Credits | Grading scale | Recurrence | Duration | Language | Level | Version |
|---|---|---|---|---|---|---|
| 3 | Grade to a tenth | Each term | 1 term | English | 4 | 1 |

| Mandatory | | | |
|---|---|---|---|
| T-MACH-103624 | X-Ray Optics | 3 CR | Last |

**Competence Certificate**
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.

**Prerequisites**
Not any.

**Competence Goal**
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

**Workload**
total 90 h, hereof 30 h contact hours (lecture), and 60 h recapitulation, homework and self-studies

**Recommendation**
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

# 7 Courses

## T 7.1 Course: Adaptive Optics [T-ETIT-107644]

**Responsible:** Dr. Szymon Gladysz
Prof. Dr. Ulrich Lemmer

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** M-ETIT-103802 - Adaptive Optics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 3 | Grade to a third | Each winter term | 1 |

| | | | | | |
|---|---|---|---|---|---|
| **Events** | | | | | |
| WT 24/25 | 2313724 | Adaptive Optics | 2 SWS | Lecture / 🗣 | Gladysz |
| **Exams** | | | | | |
| WT 24/25 | 7313724 | Adaptive Optics | | | Lemmer, Gladysz |

Legend: 🖥 Online, ✲ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

### Competence Certificate
Type of Examination: Oral examination

Duration of Examination: approx. 30 Minutes

Modality of Exam: The oral exam will be scheduled during the semester break.

The module grade is the grade of the oral exam.

### Prerequisites
None.

### Recommendation
Basic knowledge of statistics.

## T 7.2 Course: Advanced Inorganic Materials [T-CHEMBIO-103591]

**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** M-CHEMBIO-101901 - Advanced Inorganic Materials

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Oral examination | 3 | Grade to a third | 1 |

**Prerequisites**
acc. to module catalogue

## T 7.3 Course: Advanced Molecular Cell Biology [T-CHEMBIO-105196]

**Responsible:** Dr. Franco Weth
**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** M-CHEMBIO-101904 - Advanced Molecular Cell Biology

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 5 | Grade to a third | Each winter term | 2 |

**Competence Certificate**
Examination: 120min (written) (or approx. 45min (oral))

**Prerequisites**
none

**Recommendation**
Passed exam of the Adjustment Course in “Basic Molecular Cell Biology”.

**Annotation**
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.

## T 7.4 Course: Automotive Vision [T-MACH-105218]

**Responsible:** Dr. Martin Lauer
Prof. Dr.-Ing. Christoph Stiller

**Organisation:** KIT Department of Mechanical Engineering

**Part of:** M-MACH-102693 - Automotive Vision

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 4 | Grade to a third | Each summer term | 3 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 2138340 | Automotive Vision | 3 SWS | Lecture / 🗣 | Lauer, Fehler |
| **Exams** | | | | | |
| ST 2024 | 76-T-MACH-105218 | Automotive Vision | | | Stiller, Lauer |
| WT 24/25 | 76-T-MACH-105218 | Automotive Vision | | | Stiller, Lauer |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

### Competence Certificate

Type of Examination: written exam

Duration of Examination: 60 minutes

### Prerequisites

none

*Below you will find excerpts from events related to this course:*

### V Automotive Vision

2138340, SS 2024, 3 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
**Lernziele (EN):**

Machine perception and interpretation of the environment for the basis for the generation of intelligent behaviour. Especially visual perception opens the door to novel automotive applications. First driver assistance systems can already improve safety, comfort and efficiency in vehicles. Yet, several decades of research will be required to achieve an automated behaviour 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, vehicle kinematics and advanced information processing techniques are presented to provide a broad overview on ßeeing vehicles'. Application examples from cutting-edge and future driver
assistance systems illustrate the discussed subjects.

**Lehrinhalt (EN):**

1. Driver assistance systems
2. Binocular vision
3. Feature point methods
4. Optical flow/tracking in images
5. Tracking and state estimation
6. Self-localization and mapping
7. Lane recognition
8. Behavior recognition

Nachweis: Written examination 60 minutes

Arbeitsaufwand (EN): 120 hours

### Literature

Foliensatz zur Veranstaltung wird als kostenlose pdf-Datei bereitgestellt. Weitere Empfehlungen werden in der Vorlesung bekannt gegeben.

# T 7.5 Course: Basic Molecular Cell Biology [T-CHEMBIO-105199]

**Responsible:** Dr. Franco Weth
**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** M-CHEMBIO-101903 - Basic Molecular Cell Biology

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Completed coursework | 2 | pass/fail | Each summer term | 2 |

| | | | | | |
|---|---|---|---|---|---|
| **Events** | | | | | |
| ST 2024 | 7148 | Basic Molecular Cell Biology KSOP | 2 SWS | Lecture / 🗣 | Weth, Bastmeyer |
| **Exams** | | | | | |
| ST 2024 | 71105199 | Basic Molecular Cell Biology | | | Weth |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
The written exam over 120 Minutes is scheduled for the beginning of the break after the SS.
A resit exam is offered at the end of the break.

**Prerequisites**
none

**Recommendation**
Basic knowledge in General Chemistry

## T 7.6 Course: Basic Seminar Supplementary Studies on Science, Technology and Society - Self Registration [T-FORUM-113579]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading scale | Recurrence | Expansion | Version |
|---|---|---|---|---|---|
| Completed coursework | 2 | pass/fail | Each summer term | 1 terms | 1 |

**Competence Certificate**
Study achievement in the form of a presentation or a term paper or project work in the selected course.

**Prerequisites**
None

**Self service assignment of supplementary stdues**
This course can be used for self service assignment of grade aquired from the following study providers:

- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- FORUM (ehem. ZAK) Begleitstudium

**Recommendation**
It is recommended that the basic seminar be completed during the same semester as the lecture series "Science in Society". If it is not possible to attend the lecture series and the basic seminar in the same semester, the basic seminar can also be attended in the semesters before the lecture series.
However, attending courses in the advanced unit before attending the basic seminar should be avoided.

**Annotation**

## T 7.7 Course: Business Innovation in Optics and Photonics [T-ETIT-104572]

**Responsible:** Prof. Dr. Werner Nahm
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-101834 - Business Innovation in Optics and Photonics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Examination of another type | 4 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2305742 | Business Innovation in Optics and Photonics | 2 SWS | Lecture / 🗣 | Riedel, Nahm |
| WT 24/25 | 2305743 | Erxercise for 2305742 Business Innovation in Optics and Photonics | 1 SWS | Practice / 🗣 | Riedel, Nahm |
| **Exams** | | | | | |
| WT 24/25 | 7305742 | Business Innovation in Optics and Photonics | | | Nahm, Riedel |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
Type of Examination: examination of another type

Duration of Examination: 4 group presentations à 20 minutes (approx.)

Modality of Exam: The exam consists of four group presentations. 2nd day: Technology Presentation. 3rd day: Development plan presentation. 4th day: Business Canvas presentation. Final presentation at Zeiss visit: Business pitch

**Prerequisites**
none

**Recommendation**
Good knowledge in optics & photonics. Personal motivation and interest for getting deeper into business development aspects, methods and tools. Commitment to active, regular and coninuous participation in the group work.

# T 7.8 Course: Computational Photonics, without ext. Exercises [T-PHYS-106131]

**Responsible:** Prof. Dr. Carsten Rockstuhl
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-103089 - Computational Photonics, without ext. Exercises

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 4 | Grade to a third | Irregular | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 4023021 | Computational Photonics | 2 SWS | Lecture / 🗣 | Nyman, Rockstuhl |
| ST 2024 | 4023022 | Exercises to Computational Photonics | | Practice / 🗣 | Nyman, Rockstuhl |
| **Exams** | | | | | |
| ST 2024 | 7800142 | Computational Photonics, without ext. Exercises | | | Rockstuhl |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

## T 7.9 Course: Digital Signal Processing in Optical Communications – with Practical Exercises [T-ETIT-106852]

**Responsible:** Prof. Dr.-Ing. Sebastian Randel
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-103450 - Digital Signal Processing in Optical Communications – with Practical Exercises

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Examination of another type | 6 | Grade to a third | Each summer term | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 2309472 | Digital Signal Processing in Optical Communications | 2 SWS | Lecture / 🗣 | Randel |
| ST 2024 | 2309473 | Digital Signal Processing in Optical Communications (Practical Exercises) | 2 SWS | Practice / 🗣 | Randel |
| **Exams** | | | | | |
| ST 2024 | 7309472 | Digital Signal Processing in Optical Communications – with Practical Exercises | | | Randel |
| WT 24/25 | 7309472 | Digital Signal Processing in Optical Communications | | | Randel |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
The exercise sheets and the oral questionnaire are used to rate other types of examinations. The overall impression is assessed. Duration about 20 minutes.

**Prerequisites**
Basic knowledge of optical communication systems. Proven, for example, by completing one of the modules "Optical Networks and Systems-ONS", "Optoelectronic Components -OC, or" Optical Transmitters and Receivers - OTR.

**Recommendation**
Knowledge of the basics of optical communication technology and digital signal processing is helpful.

## T 7.10 Course: Elective Specialization Supplementary Studies on Science, Technology and Society / About Knowledge and Science - Self-Registration [T-FORUM-113580]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Examination of another type | 3 | Grade to a third | Each term | 1 |

**Competence Certificate**
Another type of examination assessment under § 5, section 3 involves a presentation, term paper, or project work within the chosen course.

**Prerequisites**
None

**Self service assignment of supplementary stdues**
This course can be used for self service assignment of grade aquired from the following study providers:

- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- FORUM (ehem. ZAK) Begleitstudium

**Recommendation**
The contents of the basic module are helpful. The basic module should be completed or attended in parallel, but not after the advanced module.
The reading recommendations for primary and specialist literature are determined individually by the respective lecturers according to the subject area and course.

**Annotation**
This placeholder can be used for any achievement in the Advanced Unit of the Supplementary Studies.

## T 7.11 Course: Elective Specialization Supplementary Studies on Science, Technology and Society / Science in Public Debates - Self Registration [T-FORUM-113582]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Examination of another type | 3 | Grade to a third | Each term | 1 |

**Competence Certificate**
Another type of examination assessment under § 5, section 3 involves a presentation, term paper, or project work within the chosen course.

**Prerequisites**
None

**Self service assignment of supplementary stdues**
This course can be used for self service assignment of grade aquired from the following study providers:

- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- FORUM (ehem. ZAK) Begleitstudium

**Recommendation**
The contents of the basic module are helpful. The basic module should be completed or attended in parallel, but not after the advanced module.
The reading recommendations for primary and specialist literature are determined individually by the respective lecturers according to the subject area and course.

**Annotation**
This placeholder can be used for any achievement in the Advanced Unit of the Supplementary Studies.

## T 7.12 Course: Elective Specialization Supplementary Studies on Science, Technology and Society / Science in Society - Self-Registration [T-FORUM-113581]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Examination of another type | 3 | Grade to a third | Each term | 1 |

**Competence Certificate**
Another type of examination assessment under § 5, section 3 involves a presentation, term paper, or project work within the chosen course.

**Prerequisites**
None

**Self service assignment of supplementary stdues**
This course can be used for self service assignment of grade aquired from the following study providers:

- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- FORUM (ehem. ZAK) Begleitstudium

**Recommendation**
The contents of the basic module are helpful. The basic module should be completed or attended in parallel, but not after the advanced module.
The reading recommendations for primary and specialist literature are determined individually by the respective lecturers according to the subject area and course.

**Annotation**
This placeholder can be used for any achievement in the Advanced Unit of the Supplementary Studies.

# T 7.13 Course: Electric Power Generation and Power Grid [T-ETIT-103608]

**Responsible:** Dr.-Ing. Bernd Hoferer
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-101917 - Electric Power Generation and Power Grid

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 3 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2307399 | Electric Power Generation and Power Grid | 2 SWS | Lecture / 🗣 | Hoferer |
| **Exams** | | | | | |
| ST 2024 | 737307399 | Electric Power Generation and Power Grid | | | Hoferer |
| WT 24/25 | 7307399 | Electric Power Generation and Power Grid | | | Hoferer |

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, × Cancelled

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 20 minutes

**Prerequisites**
none

## T 7.14 Course: Electromagnetics and Numerical Calculation of Fields [T-ETIT-100640]

**Responsible:** Prof. Dr.-Ing. Thomas Zwick
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100386 - Electromagnetics and Numerical Calculation of Fields

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 4 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2308263 | Electromagnetics and Numerical Calculation of Fields | 2 SWS | Lecture / 🗣 | Pauli |
| WT 24/25 | 2308265 | Exercise for 2308263 Electromagnetics and Numerical Calculation of Fields | 1 SWS | Practice / 🗣 | Pauli, Giroto de Oliveira |
| **Exams** | | | | | |
| ST 2024 | 7308263 | Electromagnetics and Numerical Calculation of Fields | | | Pauli |
| WT 24/25 | 7308263 | Electromagnetics and Numerical Calculation of Fields | | | Pauli |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
Success control is carried out in the form of a written test of 120 minutes.

**Prerequisites**
none

**Recommendation**
Fundamentals of electromagnetic field theory.

## T 7.15 Course: Fabrication and Characterisation of Optoelectronic Devices [T-ETIT-103613]

**Responsible:** Prof. Dr. Bryce Sydney Richards
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-101919 - Fabrication and Characterisation of Optoelectronic Devices

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 3 | Grade to a third | Each summer term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 2313760 | Fabrication and Characterization of Optoelectronic Devices | 2 SWS | Lecture / 🗣 | Paetzold |
| **Exams** | | | | | |
| ST 2024 | 7313760 | Fabrication and Characterisation of Optoelectronic Devices | | | Paetzold |
| WT 24/25 | 7313760 | Fabrication and Characterisation of Optoelectronic Devices | | | Paetzold |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

# T 7.16 Course: Field Propagation and Coherence [T-ETIT-100976]

**Responsible:** Prof. Dr. Wolfgang Freude
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100566 - Field Propagation and Coherence

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 4 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2309466 | Field Propagation and Coherence | 2 SWS | Lecture / 🗣 | Freude |
| WT 24/25 | 2309467 | Tutorial for 2309466 Field Propagation and Coherence | 1 SWS | Practice / 🗣 | Freude, N.N. |
| **Exams** | | | | | |
| ST 2024 | 7309466 | Field Propagation and Coherence | | | Freude |
| WT 24/25 | 7309466 | Field Propagation and Coherence | | | Freude |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

## T 7.17 Course: Fundamentals of Optics and Photonics [T-PHYS-103628]

**Responsible:** Prof. Dr. David Hunger
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-101927 - Fundamentals of Optics and Photonics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 8 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 4044021 | KSOP - Fundamentals of Optics & Photonics | 4 SWS | Lecture / 🗣 | Kreysing, Lemmer |
| WT 24/25 | 4044022 | KSOP - Exercises to Fundamentals of Optics & Photonics | 2 SWS | Practice / 🗣 | Hunger, Palkhivala |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
Successfull participation in the exercises

**Modeled Conditions**
The following conditions have to be fulfilled:

1. The course T-PHYS-103630 - Fundamentals of Optics and Photonics - Unit must have been passed.

# T 7.18 Course: Fundamentals of Optics and Photonics - Unit [T-PHYS-103630]

**Responsible:** Prof. Dr. David Hunger
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-101927 - Fundamentals of Optics and Photonics

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Completed coursework | 0 | pass/fail | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 4044021 | KSOP - Fundamentals of Optics & Photonics | 4 SWS | Lecture / 🗣 | Kreysing, Lemmer |
| WT 24/25 | 4044022 | KSOP - Exercises to Fundamentals of Optics & Photonics | 2 SWS | Practice / 🗣 | Hunger, Palkhivala |

Legend: 🖥 Online, ❁ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

## T 7.19 Course: Imaging Techniques in Light Microscopy [T-CHEMBIO-105197]

**Responsible:** Prof. Dr. Martin Bastmeyer
**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** M-CHEMBIO-101905 - Imaging Techniques in Light Microscopy

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 3 | Grade to a third | Each winter term | 3 |

**Competence Certificate**
Written exam over 120 minutes (depending on the number of participants oral exam over approx.45 min).

Depending on the number of participants, a written exam (120 min) or an oral exam (approx.45 min) 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.

**Prerequisites**
none

**Recommendation**
Attendance to the lecture. Basic knowledge in physics and biology.

## T 7.20 Course: Internship Presentation [T-ETIT-105127]

**Responsible:** Prof. Dr. Ulrich Lemmer
Prof. Dr.-Ing. Christoph Stiller

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** M-ETIT-102360 - Internship

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Completed coursework | 12 | pass/fail | Each term | 4 |

| Exams | | | |
|---|---|---|---|
| ST 2024 | 7390002 | Internship | Lemmer, Stiller |
| ST 2024 | 7390002-2 | Internship | Lemmer, Stiller |
| WT 24/25 | 7390002 | Internship | Lemmer, Stiller |

**Competence Certificate**
The internship is a study achievement (study and examinations Regulation, § 4 (3)). A minimum of working hours equivalent to 8 weeks of full-time work (excluding holidays and public holidays) must be completed.

Furthermore the following three parts must be provided:

1: A company confirmation about the completion of the internship

**Internship confirmation/certificate from industry or research institute.**

The interns***h***ip confirmation is issued directly by the company or institute, respectively, after the internship is completed. 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 Name (institute, sector and supervisor). Please note that the internship contract is not valid as a certificate.

**2. Delivery of a written report on methodology and results (approx. 10 pages).**

The internship report comprises a written report in the form of a seminar paper and an evaluation to be handed in to the KSOP student office.

-> Both documents (company confirmation and internship report) have to be send to the KSOP Office latest 2 weeks before the presentation date.

3. **Presentation**

In the internship presentation the students have to present the project work of their internships to a KSOP professor and their peers (who make the presentation on the same day; usually up to 15 students) followed by a discussion of the results.

For the presentation several dates (usually one every three month) are available per year. The dates are announced twice a year to the current students and students need to register online for the desired presentation date latest 15 days before the desired presentation date. After that the registration will be closed.

The 12 credit points are awarded after passing the company confirmation, internship report and presentation. The decision is made by a KSOP professor.

**Prerequisites**
Scientific background in Optics and Photonics

**Recommendation**
Scientific background in Optics and Photonics.

## T 7.21 Course: Introduction to Automotive and Industrial Lidar Technology [T-ETIT-111011]

**Responsible:** Prof. Dr. Wilhelm Stork
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-105461 - Introduction to Automotive and Industrial Lidar Technology

| Type | Credits | Grading scale | Recurrence | Expansion | Version |
|---|---|---|---|---|---|
| Examination of another type | 3 | Grade to a third | Each winter term | 1 terms | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2311604 | Introduction to automotive and industrial Lidar technology | 2 SWS | Lecture / Blended (On-Site/Online) | Stork, Heußner |
| **Exams** | | | | | |
| WT 24/25 | 7311604 | Introduction to automotive and industrial Lidar technology | | | Stork, Heußner |

Legend: Online, Blended (On-Site/Online), On-Site, ✕ Cancelled

## T 7.22 Course: Introduction to the Scientific Method (Seminar, Englisch) [T-ETIT-111317]

**Responsible:** Prof. Dr. Werner Nahm
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-105665 - Introduction to the Scientific Method (Seminar, English)

| Type | Credits | Grading scale | Recurrence | Expansion | Version |
|---|---|---|---|---|---|
| Completed coursework | 1 | pass/fail | Each term | 1 terms | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 2305745 | Introduction to the Scientific Method | 1 SWS | Seminar / 🗣 | Nahm |
| WT 24/25 | 2305746 | Introduction to the Scientific Method | 1 SWS | Seminar / 🗣 | Nahm |
| **Exams** | | | | | |
| ST 2024 | 7305745 | Introduction to the scientific method (Seminar, englisch) | | | Nahm |
| WT 24/25 | 7305745 | Introduction to the Scientific Method (Seminar, Englisch) | | | Nahm |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, × Cancelled

**Competence Certificate**
The sucess control takes place in the form of a study achievement. The exam consists of the preparation and the presentation of a seminar paper.

**Prerequisites**
none

**Annotation**
Detailled information on contents, competence goals, and work load at:
M-ETIT-105665 – Introduction to the Scientific Method (Seminar)

## T 7.23 Course: Laser Metrology [T-ETIT-100643]

**Responsible:** Prof. Dr. Marc Eichhorn
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100434 - Laser Metrology

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 3 | Grade to a third | Each summer term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 2303200 | Laser Metrology | 2 SWS | Lecture / 🗣 | Eichhorn |
| **Exams** | | | | | |
| ST 2024 | 7303200 | Laser Metrology | | | Eichhorn |
| WT 24/25 | 7303200 | Laser Metrology | | | Eichhorn |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
Type of Examination: Oral examination

Duration of Examination: approx. 30 minutes

**Prerequisites**
none

*Below you will find excerpts from events related to this course:*

**V Laser Metrology** — **Lecture (V) On-Site**
2303200, SS 2024, 2 SWS, Language: English, Open in study portal

**Content**
Current time schedule can be found in ILIAS

**Organizational issues**
Beginn am Do. 25. April, 9:45 - 13:15

Seminarraum IRS, Raum 312 Geb. 30.33.

Weitere Details werden in ILIAS bekannt gegeben. Prüfungen werden ebenfalls über ILIAS organisiert

Starting on Thursday, 25.April, 9:45 - 13:15

Room 312, Building 30.33

Further details are annouced in ILIAS. Exam registration will also be organised via ILIAS.

# T 7.24 Course: Laser Physics [T-ETIT-100741]

**Responsible:** Prof. Dr. Marc Eichhorn
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100435 - Laser Physics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 4 | Grade to a third | Each winter term | 1 |

| **Events** | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2301480 | Laserphysics | 2 SWS | Lecture / 🧩 | Eichhorn |
| WT 24/25 | 2301481 | Exercise for 2301480 Laserphysics | 1 SWS | Practice / 🧩 | Eichhorn |
| **Exams** | | | | | |
| ST 2024 | 7300023 | Laser Physics | | | Eichhorn |
| WT 24/25 | 737300030 | Laser Physics | | | Eichhorn |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

### Competence Certificate
Type of Examination: Oral examination

Duration of Examination: approx. 30 minutes

### Prerequisites
none

## T 7.25 Course: Lecture Series Supplementary Studies on Science, Technology and Society - Self Registration [T-FORUM-113578]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading scale | Recurrence | Expansion | Version |
|---|---|---|---|---|---|
| Completed coursework | 2 | pass/fail | Each summer term | 1 terms | 1 |

**Competence Certificate**
Active participation, learning protocols, if applicable.

**Prerequisites**
None

**Self service assignment of supplementary stdues**
This course can be used for self service assignment of grade aquired from the following study providers:

- Studium Generale. Forum Wissenschaft und Gesellschaft (FORUM) (ehem. ZAK)
- FORUM (ehem. ZAK) Begleitstudium

**Recommendation**
It is recommended that you complete the lecture series "Science in Society" before attending events in the advanced module and in parallel with attending the basic seminar.
If it is not possible to attend the lecture series and the basic seminar in the same semester, the lecture series can also be attended after attending the basic seminar.
However, attending events in the advanced module before attending the lecture series should be avoided.

**Annotation**
The basic module consists of the lecture series "Science in Society" and the basic seminar. The lecture series is only offered during the summer semester.
The basic seminar can be attended in the summer or winter semester.

## T 7.26 Course: Light and Display Engineering [T-ETIT-100644]

**Responsible:** Dr.-Ing. Rainer Kling
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100512 - Light and Display Engineering

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 4 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2313747 | Light and Display Engineering | 2 SWS | Lecture / 🗣 | Kling |
| WT 24/25 | 2313749 | Übungen zu 2313747 Light and Display Engineering | 1 SWS | Practice / 🗣 | Kling |
| **Exams** | | | | | |
| ST 2024 | 7313747 | Light and Display Engineering | | | Kling |
| WT 24/25 | 7313747 | Light and Display Engineering | | | Kling |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
Type of Examination: Oral exam

Duration of Examination: approx. 25 minutes

**Prerequisites**
none

## T 7.27 Course: Lighting Design - Theory and Applications [T-ETIT-100997]

**Responsible:** Dr.-Ing. Rainer Kling
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100577 - Lighting Design - Theory and Applications

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 3 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2313751 | Lighting Design - Theory and Applications | 2 SWS | Seminar / 🗣 | Kling |
| **Exams** | | | | | |
| ST 2024 | 7313751 | Lighting Design - Theory and Applications | | | Kling |
| WT 24/25 | 7313751 | Lighting Design - Theory and Applications | | | Kling |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

### Competence Certificate
Type of Examination: Oral exam

Duration of Examination: approx. 25 minutes

### Prerequisites
none

# T 7.28 Course: Machine Vision [T-MACH-105223]

**Responsible:** Dr. Martin Lauer
Prof. Dr.-Ing. Christoph Stiller

**Organisation:** KIT Department of Mechanical Engineering

**Part of:** M-MACH-101923 - Machine Vision

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 6 | Grade to a third | Each winter term | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2137308 | Machine Vision | 4 SWS | Lecture / Practice ( / 🗣 | Lauer, Merkert |
| **Exams** | | | | | |
| ST 2024 | 76-T-MACH-105223 | Machine Vision | | | Stiller, Lauer |
| WT 24/25 | 76-T-MACH-105223 | Machine Vision | | | Stiller, Lauer |

Legend: 🖥 Online, ❖ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

### Competence Certificate
Type of Examination: written exam

Duration of Examination: 60 minutes

### Prerequisites
None

*Below you will find excerpts from events related to this course:*

## V Machine Vision
2137308, WS 24/25, 4 SWS, Language: English, Open in study portal

**Lecture / Practice (VÜ)**
**On-Site**

### Content
Lernziele (EN):

*Machine vision* (or *computer vision*) describes all kind of techniques that can be used to extract information from camera images in an automated way. Considerable improvements of machine vision techniques throughout recent years, e.g. by the advent of deep learning, have caused growing interest in these techniques and enabled applications in various domains, e.g. robotics, autonomous driving, gaming, production control, visual inspection, medicine, surveillance systems, and augmented reality.

The participants should gain an overview over the basic techniques in machine vision and obtain hands-on experience.

Nachweis: written exam, 60 min.

Arbeitsaufwand: 240 hours

Voraussetzungen: none

### Literature
Foliensatz zur Veranstaltung wird als kostenlose pdf-Datei bereitgestellt.Weitere Empfehlungen
werden in der Vorlesung bekannt gegeben.

## T 7.29 Course: Master's Thesis [T-ETIT-104732]

**Responsible:** Prof. Dr. Cornelius Neumann

**Organisation:** KIT Department of Electrical Engineering and Information Technology

**Part of:** M-ETIT-102362 - Module Master's Thesis

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Final Thesis | 30 | Grade to a third | 1 |

**Competence Certificate**

The master’s thesis module consists of the master’s thesis and a presentation. The presentation shall be made within six months upon registration for the master’s thesis.

**Prerequisites**

Prerequisites according to:

**Study and Examination Regulations of Karlsruhe Institute of Technology (KIT) Relating to the Master’s Program “Optics & Photonics” (dated August 04, 2015)**

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.

**Modeled Conditions**

The following conditions have to be fulfilled:

1. The course T-ETIT-105575 - Precondition Master's Thesis must have been passed.

**Final Thesis**

This course represents a final thesis. The following periods have been supplied:

| | |
|---|---|
| **Submission deadline** | 6 months |
| **Maximum extension period** | 3 months |
| **Correction period** | 8 weeks |

This thesis requires confirmation by the examination office.

# T 7.30 Course: Measurement and Control Systems [T-MACH-103622]

**Responsible:** Prof. Dr.-Ing. Christoph Stiller
**Organisation:** KIT Department of Mechanical Engineering

**Part of:** M-MACH-101921 - Measurement and Control Systems

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 6 | Grade to a third | Each winter term | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 3137020 | Measurement and Control Systems | 3 SWS | Lecture / 🗣 | Stiller |
| WT 24/25 | 3137021 | Measurement and Control Systems (Tutorial) | 1 SWS | Practice / 🗣 | Stiller |
| **Exams** | | | | | |
| ST 2024 | 76-T-MACH-103622 | Measurement and Control Systems | | | Stiller, Pauls |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
oral exam (30 min)

**Prerequisites**
none

*Below you will find excerpts from events related to this course:*

## V Measurement and Control Systems

3137020, WS 24/25, 3 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

**Content**
**Lehrinhalt (EN):**

1 Dynamic systems
2 Properties of important systems and modeling
3 Transfer characteristics and stability
4 Controller design
5 Fundamentals of measurement
6 Estimation
7 Sensors
8 Introduction to digital measuremen

**Lernhziele (EN):**

Measurement and control of physical entities is a vital requirement in most technical applications. Such entities may comprise e.g. pressure, temperature, flow, rotational speed, power, voltage and electrical current, etc.. From a general perspective, the objective of measurement is to obtain information about the state of a system while control aims to influence the state of a system in a desired manner. This lecture provides an introduction to this field and general systems theory. The control part of the lecture presents classical linear control theory. The measurement part discusses electrical measurement of non-electrical entities.

Nachweis (EN): written exam; duration 2,5 h; paper reference materials only (no calculator)

Arbeitsaufwand (EN): 180 hours

**Organizational issues**
Die Vorlesung startet am 22.10.2024.

**Literature**

- Measurement and Control Systems:

R.H. Cannon: Dynamics of Physical Systems, McGraw-Hill Book Comp., New York,1967
G.F. Franklin: Feedback Control of Dynamic Systems, Addison-Wesley Publishing Company, USA, 1988
R. Dorf and R. Bishop: Modern Control Systems, Addison-Wesley
C. Phillips and R. Harbor: Feedback Control Systems, Prentice-Hall

- Regelungstechnische Bücher:

J. Lunze: Regelungstechnik 1 & 2, Springer-Verlag
R. Unbehauen: Regelungstechnik 1 & 2, Vieweg-Verlag
O. Föllinger: Regelungstechnik, Hüthig-Verlag
W. Leonhard: Einführung in die Regelungstechnik, Teubner-Verlag
Schmidt, G.: Grundlagen der Regelungstechnik, Springer-Verlag, 2. Aufl., 1989

- Messtechnische Bücher:

E. Schrüfer: Elektrische Meßtechnik, Hanser-Verlag, München, 5. Aufl., 1992
U. Kiencke, H. Kronmüller, R. Eger: Meßtechnik, Springer-Verlag, 5. Aufl., 2001
H.-R. Tränkler: Taschenbuch der Messtechnik, Verlag Oldenbourg München, 1996
W. Pfeiffer: Elektrische Messtechnik, VDE Verlag Berlin 1999
Kronmüller, H.: Prinzipien der Prozeßmeßtechnik 2, Schnäcker-Verlag, Karlsruhe, 1. Aufl., 1980

**V** **Measurement and Control Systems (Tutorial)**
3137021, WS 24/25, 1 SWS, Language: English, Open in study portal

**Practice (Ü)**
**On-Site**

**Content**
Tutorial for Measurement and Control Systems

# T 7.31 Course: Modern Physics [T-PHYS-103629]

**Responsible:** apl. Prof. Dr. Bernd Pilawa
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-101931 - Modern Physics

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Written examination | 6 | Grade to a third | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 4044011 | KSOP - Modern Physics | 4 SWS | Lecture / 🗣 | Pilawa |
| WT 24/25 | 4044012 | KSOP - Exercises to Modern Physics | 2 SWS | Practice / 🗣 | Pilawa, Tohamy |
| **Exams** | | | | | |
| ST 2024 | 7800020 | Modern Physics (MSc Optics & Photonics, KSOP) | | | Pilawa |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
Written exam (usually about 180 min)

**Prerequisites**
none

## T 7.32 Course: Molecular Spectroscopy [T-CHEMBIO-101864]

**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** M-CHEMBIO-101902 - Molecular Spectroscopy

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Oral examination | 4 | Grade to a third | 1 |

**Prerequisites**
acc. to module catalogue

# T 7.33 Course: Nano-Optics [T-PHYS-102282]

**Responsible:** PD Dr. Andreas Naber
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-102146 - Nano-Optics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 6 | Grade to a third | Each winter term | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 4020021 | Nano-Optics | 3 SWS | Lecture / 🗣 | Naber |
| WT 24/25 | 4020022 | Exercises to Nano-Optics | 1 SWS | Practice / 🗣 | Naber |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

## 7.34 Course: Nonlinear Optics [T-ETIT-101906]

**Responsible:** Prof. Dr.-Ing. Christian Koos
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100430 - Nonlinear Optics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 4 | Grade to a third | Each summer term | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 2309468 | Nonlinear Optics | 2 SWS | Lecture / 🗣 | Koos |
| ST 2024 | 2309469 | Nonlinear Optics (Tutorial) | 2 SWS | Practice / 🗣 | Koos |
| **Exams** | | | | | |
| ST 2024 | 7309468 | Nonlinear Optics | | | Koos |
| WT 24/25 | 7309468 | Nonlinear Optics | | | Koos |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 30 Minutes

Modality of Exam: The oral exam is offered continuously upon individual appointment.

**Prerequisites**
none

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

## T 7.35 Course: Optical Engineering [T-ETIT-100676]

**Responsible:** Prof. Dr. Wilhelm Stork
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100456 - Optical Engineering

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 4 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2311629 | Optical Engineering | 2 SWS | Lecture / 🧩 | Stork |
| WT 24/25 | 2311631 | Tutorial for 2311629 Optical Engineering | 1 SWS | Practice / 🧩 | Fan |
| **Exams** | | | | | |
| ST 2024 | 7311730 | Optical Engineering | | | Stork |
| WT 24/25 | 7311629 | Optical Engineering | | | Stork |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
Achievement will be examined in an oral examination (approx. 20 minutes)

**Prerequisites**
none

**Recommendation**
Solid mathematical background.

## T 7.36 Course: Optical Networks and Systems [T-ETIT-106506]

**Responsible:** Prof. Dr.-Ing. Sebastian Randel
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-103270 - Optical Networks and Systems

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 4 | Grade to a third | Each winter term | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2309470 | Optical Networks and Systems | 2 SWS | Lecture / 🗣 | Randel |
| WT 24/25 | 2309471 | Tutorial for 2309470 Optical Networks and Systems | 1 SWS | Practice / 🗣 | Randel, N.N. |
| **Exams** | | | | | |
| ST 2024 | 7309470 | Optical Networks and Systems | | | Randel |
| ST 2024 | 73101907 | Optical Networks and Systems -repetition exam | | | Randel |
| WT 24/25 | 7309470 | Optical Networks and Systems | | | Randel |

Legend: 🖥 Online, ✲ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

### Competence Certificate
Type of Examination: oral exam

Duration of Examination: 20 min (approx.)

Modality of Exam: Oral exams (approx. 20 minutes) are offered throughout the year upon individual appointment.

### Prerequisites
none

### Recommendation
Interest in communications engineering, networking, and photonics.

# T 7.37 Course: Optical Systems in Medicine and Life Science [T-ETIT-106462]

**Responsible:** Prof. Dr. Werner Nahm
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-103252 - Optical Systems in Medicine and Life Science

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 3 | Grade to a third | Each summer term | 3 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2305292 | Optical Systems in Medicine and Life Science | 2 SWS | Lecture / ✕ | Hoffmann, Nahm |
| **Exams** | | | | | |
| ST 2024 | 7300012 | Optical Systems in Medicine and Life Science | | | Nahm |
| WT 24/25 | 7305292 | Optical Systems in Medicine and Life Science | | | Nahm |

Legend: Online, Blended (On-Site/Online), On-Site, ✕ Cancelled

**Competence Certificate**
Written exam (60 minutes)

**Prerequisites**
none

**Recommendation**
Good understanding of optics and optoelectronics.

**Annotation**
Language English

# T 7.38 Course: Optical Transmitters and Receivers [T-ETIT-100639]

**Responsible:** Prof. Dr. Wolfgang Freude
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100436 - Optical Transmitters and Receivers

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 6 | Grade to a third | Each winter term | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2309460 | Optical Transmitters and Receivers | 2 SWS | Lecture / 🗣 | Freude |
| WT 24/25 | 2309461 | Tutorial for 2309460 Optical Transmitters and Receivers | 2 SWS | Practice / 🗣 | Freude, N.N. |
| **Exams** | | | | | |
| ST 2024 | 7309460 | Optical Transmitters and Receivers | | | Freude |
| WT 24/25 | 7309460 | Optical Transmitters and Receivers | | | Freude |

Legend: 🖥 Online, ✲ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

# T 7.39 Course: Optical Waveguides and Fibers [T-ETIT-101945]

**Responsible:** Prof. Dr.-Ing. Christian Koos
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100506 - Optical Waveguides and Fibers

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 4 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2309464 | Optical Waveguides and Fibers | 2 SWS | Lecture / 🗣 | Koos, N.N., Bao |
| WT 24/25 | 2309465 | Tutorial for 2309464 Optical Waveguides and Fibers | 1 SWS | Practice / 🗣 | Koos, N.N. |
| **Exams** | | | | | |
| ST 2024 | 7309464 | Optical Waveguides and Fibers | | | Koos |
| WT 24/25 | 7309464 | Optical Waveguides and Fibers | | | Koos |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

# T 7.40 Course: Optics and Photonics Lab [T-PHYS-104511]

**Responsible:** PD Dr. Michael Hetterich
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-102189 - Optics and Photonics Lab

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Completed coursework | 10 | pass/fail | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 2309491 | Optics and Photonics Lab (KSOP) | 4 SWS | Practical course / 🗣 | Koos, Freude, Randel |
| ST 2024 | 4044123 | KSOP Optics & Photonics Lab II | 4 SWS | Practical course / 🗣 | Hetterich |
| ST 2024 | 5254 | Praktikum Optics and Photonics Lab II (KSOP) | 4 SWS | Practical course / 🗣 | Kappes, Unterreiner, Lebedkin |
| ST 2024 | 7146 | KSOP Optics and Photonics Lab II | 4 SWS | Practical course / 🗣 | Bastmeyer, Weth |
| WT 24/25 | 2309491 | Optics & Photonics Lab KSOP | 4 SWS | Practical course / 🗣 | Freude, Koos, Randel, N.N. |
| WT 24/25 | 4044113 | KSOP - Optics & Photonics Lab I | 4 SWS | Practical course / 🗣 | Hetterich |
| WT 24/25 | 7287 | KSOP Optics and Photonics Lab I | | Practical course / 🗣 | Bastmeyer, Weth |
| **Exams** | | | | | |
| ST 2024 | 7800071 | Optics and Photonics Lab | | | Hetterich |

Legend: 🖥 Online, Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
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 tobias.siegle@kit.edu), so that they can be registered with the respective department´s labs. The successful completion of an individual lab is awared 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 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.

**Prerequisites**
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.

**Recommendation**
Basic background in optics and photonics, as well as physics.

## T 7.41 Course: Optics and Vision in Biology [T-CHEMBIO-105198]

**Responsible:** Prof. Dr. Martin Bastmeyer
**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** M-CHEMBIO-101906 - Optics and Vision in Biology

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 4 | Grade to a third | Each winter term | 2 |

**Competence Certificate**
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.

**Prerequisites**
none

**Recommendation**
Passed exam of the Adjustment Course in "Basic Molecular Cell Biology" AdjC-BMCB.

Attendance to the lecture.

**Annotation**
Prerequisite for exam participation: Passed exam of the Adjustment Course in “Basic Molecular Cell Biology”.
Anmerkungen engl.

# T 7.42 Course: Optoelectronic Components [T-ETIT-101907]

**Responsible:** Prof. Dr.-Ing. Sebastian Randel
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100509 - Optoelectronic Components

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 4 | Grade to a third | Each summer term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 2309486 | Optoelectronic Components | 2 SWS | Lecture / 🧩 | Randel |
| ST 2024 | 2309487 | Optoelectronic Components (Tutorial) | 1 SWS | Practice / 🧩 | Randel |
| **Exams** | | | | | |
| ST 2024 | 7300027 | Optoelectronic Components - repetition exam | | | Randel |
| ST 2024 | 7309486 | Optoelectronic Components | | | Randel |
| WT 24/25 | 7309486 | Optoelectronic Components | | | Randel |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
Type of Examination: oral exam

Duration of Examination: approx. 30 minutes

**Prerequisites**
none

## T 7.43 Course: Organic Photochemistry [T-CHEMBIO-105195]

**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** M-CHEMBIO-101907 - Organic Photochemistry

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Oral examination | 3 | Grade to a third | 1 |

**Prerequisites**

acc. to module catalogue

## T 7.44 Course: Photonic Integrated Circuit Design and Applications [T-ETIT-111896]

**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-105914 - Photonic Integrated Circuit Design and Applications

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Examination of another type | 6 | Grade to a third | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 2309478 | Photonic Integrated Circuit Design and Applications | 2 SWS | Lecture / 🧩 | Koos, Freude, Randel |
| ST 2024 | 2309479 | Photonic Integrated Circuit Design and Applications (Practical Exercise) | 2 SWS | Practical course / 🧩 | Koos, Freude, Randel |
| **Exams** | | | | | |
| ST 2024 | 7300005 | Photonic Integrated Circuit Design and Applications | | | Freude, Randel, Koos |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

### Competence Certificate

- Part 1 – Solutions of problem sets: We will grade your solutions of the various problem sets and design projects. To this end, please upload your solution via the online teaching platform of your respective institution (see above) before the respective deadline. Please merge all pages into a single pdf file, and please use a scanner. Smartphone made snapshots are often illegible, and in this case your solutions cannot not be evaluated. In case there are any technical difficulties with the platforms, you may also submit your solutions by e-mail to picda@ipq.kit.edu before the respective deadline.
- Part 2 - Presentation of one pre-assigned problem set: At the beginning of the term, design projects will be pre-assigned to groups of participants. Each of these groups will explain their approach and results to lecturers and peer students in a short presentation (approx. 15 min), followed by approx. 10 min of public discussion with peer students and professors, and an individual private interview of each group member (approx. 10 min per person).

The overall impression is rated.

### Prerequisites
none

## T 7.45 Course: Plastic Electronics / Polymerelectronics [T-ETIT-100763]

**Responsible:** Prof. Dr. Ulrich Lemmer
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100475 - Plastic Electronics / Polymerelectronics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 3 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2313709 | Polymerelectronics/ Plastic Electronics | 2 SWS | Lecture / (Blended) | Hernandez Sosa |
| **Exams** | | | | | |
| ST 2024 | 7313709 | Plastic Electronics / Polymerelectronics | | | Lemmer, Hernandez Sosa |
| WT 24/25 | 7313709 | Plastic Electronics / Polymerelectronics | | | Lemmer, Hernandez Sosa |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Competence Certificate**
The control of success takes place within the framework of an oral overall examination (approx. 30 minutes).

**Prerequisites**
none

**Recommendation**
Knowledge of semiconductor components.

**Annotation**
Lecture and examination are held in German or English, as required.

## T 7.46 Course: Quantum Optics [T-PHYS-106135]

**Responsible:** Prof. Dr. Anja Metelmann
Prof. Dr. Carsten Rockstuhl

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-103093 - Quantum Optics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 4 | Grade to a third | Each winter term | 2 |

## T 7.47 Course: Quantum Optics at the Nano Scale, with Exercises [T-PHYS-113126]

**Responsible:** Prof. Dr. David Hunger
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-106508 - Quantum Optics at the Nano Scale, with Exercises

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 8 | Grade to a third | Irregular | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 4021161 | Quantum Optics at the Nano Scale | 3 SWS | Lecture / 🗣 | Hunger |
| ST 2024 | 4021162 | Exercises to Quantum Optics at the Nano Scale | 1 SWS | Practice / 🗣 | Hunger, Laukó |
| **Exams** | | | | | |
| ST 2024 | 7800120 | Quantum Optics at the Nano Scale, with Exercises | | | Hunger |

Legend: 🖥 Online, 🧩 Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

## T 7.48 Course: Quantum Optics at the Nano Scale, without Exercises [T-PHYS-113128]

**Responsible:** Prof. Dr. David Hunger
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-106510 - Quantum Optics at the Nano Scale, without Exercises

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 6 | Grade to a third | Irregular | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 4021161 | Quantum Optics at the Nano Scale | 3 SWS | Lecture / 🗣 | Hunger |
| **Exams** | | | | | |
| ST 2024 | 7800121 | Quantum Optics at the Nano Scale, without Exercises | | | Hunger |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

## T 7.49 Course: Registration for Certificate Issuance - Supplementary Studies on Science, Technology and Society [T-FORUM-113587]

**Responsible:** Dr. Christine Mielke
Christine Myglas

**Organisation:**

**Part of:** M-FORUM-106753 - Supplementary Studies on Science, Technology and Society

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Completed coursework | 0 | pass/fail | Each term | 1 |

**Prerequisites**
In order to register, it is mandatory that the basic module and the advanced module have been completed and that the grades for the partial performances in the advanced module are available.

## T 7.50 Course: Research Project [T-PHYS-103632]

**Responsible:** Prof. Dr. Carsten Rockstuhl
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-102194 - Research Project

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Examination of another type | 4 | Grade to a third | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 4044033 | KSOP Research Project | 4 SWS | Project (P / 🗣 | Rockstuhl |
| **Exams** | | | | | |
| WT 24/25 | 7800097 | Research Project | | | Rockstuhl |

Legend: 🖥 Online, ✿ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

## T 7.51 Course: Seminar Course [T-PHYS-104516]

**Responsible:** Prof. Dr. David Hunger
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-102195 - Seminar Course

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Completed coursework | 4 | pass/fail | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 4044024 | KSOP - Seminar Course (3 Courses) | 2 SWS | Seminar / 🗣 | Hunger, Rosemann |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

# T 7.52 Course: Solar Energy [T-ETIT-100774]

**Responsible:** Prof. Dr. Bryce Sydney Richards
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100524 - Solar Energy

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 6 | Grade to a third | Each winter term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2313745 | Solar Energy | 3 SWS | Lecture / | Richards, Paetzold |
| WT 24/25 | 2313750 | Tutorial 2313745 Solar Energy | 1 SWS | Practice / | Richards, Paetzold |
| **Exams** | | | | | |
| ST 2024 | 7313745 | Solar Energy | | | Richards, Paetzold |
| WT 24/25 | 7313745 | Solar Energy | | | Richards, Paetzold |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Prerequisites**
Students not allowed to take either of the following modules in addition to this one: „Solarenergie“ (M-ETIT-100476) and „Photovoltaik“ (M-ETIT-100513).

# T 7.53 Course: Solar Thermal Energy Systems [T-MACH-106493]

**Responsible:** apl. Prof. Dr. Ron Dagan
**Organisation:** KIT Department of Mechanical Engineering

**Part of:** M-MACH-101924 - Solar Thermal Energy Systems

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 3 | Grade to a third | Each winter term | 4 |

| **Events** | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2189400 | Solar Thermal Energy Systems | 2 SWS | Lecture / 🗣 | Dagan |
| **Exams** | | | | | |
| ST 2024 | 76106493 | Repetition: Solar Thermal Energy Systems | | | Dagan |
| ST 2024 | 76-T-MACH-106493 | Solar Thermal Energy Systems | | | Dagan |
| WT 24/25 | 76-T-MACH-106493 | Solar Thermal Energy Systems | | | Dagan |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Competence Certificate**
oral exam of about 30 minutes

**Prerequisites**
none

**Recommendation**
Literature

1. "Solar Engineering of Thermal Processes", 4th Edition, J. Duffie &W. Beckman. Published by Wiley & Sons
2. “Heat Transfer”, 10th Edition, J. P. Holman Mc. Graw Hill publisher
3. “Fundamentals of classical Thermodynamics”, G. Van Wylen & R. E. Sonntag. Published by Wiley &Sons

*Below you will find excerpts from events related to this course:*

## V Solar Thermal Energy Systems

2189400, WS 24/25, 2 SWS, Language: English, Open in study portal

**Lecture (V)**
**On-Site**

**Content**

The course deals with fundamental aspects of solar energy

1. Introduction to solar energy – global energy panorama

2. Solar energy resource-

Structure of the sun, Black body radiation, solar constant, solar spectral distribution

Sun-Earth geometrical relationship

3. Passive and active solar thermal applications.

4. Solar thermal systems- solar collector-types, concentrating collectors, solar towers,
 Heat losses, efficiency

5. Selected topics on thermodynamics and heat transfer which are relevant for solar systems.

6. Introduction to Solar induced systems: Wind , Heat pumps, Biomass , Photovoltaic

7. 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.

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.

Total 120 h, hereof 30 h contact hours and 90 h homework and self-studies

oral exam about 30 min.

**Organizational issues**

Die Vorlesung "Thermische Solarenergie" findet ab dem WS 2024/25 nicht mehr statt. Sie wurde zusammengelegt mit der engl. Version "Solar Thermal Energy Systems"

**Literature**


- “Solar Engineering of Thermal Processes “4th Edition, J. Duffie &W. Beckman. Published by Wiley & Sons.
- “Heat Transfer”, 10th Edition, P. Holman Mc. Graw Hill publisher.
- “Fundamentals of classical Thermodynamics”, G. Van Wylen & R. E. Sonntag. Published by Wiley & Sons

## T 7.54 Course: Solid-State Optics, without Exercises [T-PHYS-104773]

**Responsible:** PD Dr. Michael Hetterich
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-102408 - Solid-State Optics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Oral examination | 6 | Grade to a third | Each winter term | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 4020011 | Solid-State-Optics | 4 SWS | Lecture / 🗣 | Hetterich |
| **Exams** | | | | | |
| WT 24/25 | 7800104 | Solid-State Optics, without Exercises | | | Hetterich |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

## T 7.55 Course: Spectroscopic Methods [T-CHEMBIO-103590]

**Organisation:** KIT Department of Chemistry and Biosciences
**Part of:** M-CHEMBIO-101900 - Spectroscopic Methods

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Written examination | 3 | Grade to a third | 1 |

| Exams | | | |
|---|---|---|---|
| ST 2024 | 718200121 | Spectroscopic Methods | Kappes, Unterreiner |
| WT 24/25 | 7100021_2 | Spectroscopic Methods Resit | Kappes, Unterreiner |

**Prerequisites**
acc. to module catalogue

# T 7.56 Course: Systems and Software Engineering [T-ETIT-100675]

**Responsible:** Prof. Dr.-Ing. Eric Sax
**Organisation:** KIT Department of Electrical Engineering and Information Technology
**Part of:** M-ETIT-100537 - Systems and Software Engineering

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 4 | Grade to a third | Each winter term | 2 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 2311605 | Systems and Software Engineering | 2 SWS | Lecture / Blended | Sax |
| WT 24/25 | 2311607 | Tutoral for 2311605 Systems and Software Engineering | 1 SWS | Practice / Blended | Nägele |
| **Exams** | | | | | |
| ST 2024 | 7311605 | Systems and Software Engineering | | | Sax |
| WT 24/25 | 7311605 | Systems and Software Engineering | | | Sax |

Legend: Online, Blended (On-Site/Online), On-Site, Cancelled

**Competence Certificate**
Written exam, approximately 90 minutes.

Students are given the opportunity to earn a grade bonus through separate task assignments. If the grade of the written exam is between 4.0 and 1.3, the bonus improves the grade by a maximum of one grade level (0.3 or 0.4). The exact criteria for awarding a bonus will be announced at the beginning of the lecture. Bonus points do not expire and remain valid for exams taken at a later date:

The grade is determined by the written exam and the bonus points.

**Prerequisites**
none

## T 7.57 Course: Theoretical Nanooptics [T-PHYS-104587]

**Responsible:** Prof. Dr. Markus Garst
Prof. Dr. Carsten Rockstuhl

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102295 - Theoretical Nanooptics

| Type | Credits | Grading scale | Version |
|---|---|---|---|
| Oral examination | 6 | Grade to a third | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| WT 24/25 | 4023131 | Theoretical Nanooptics | 2 SWS | Lecture / 🗣 | Rockstuhl, Fernandez Corbaton |
| WT 24/25 | 4023132 | Exercises to Theoretical Nanooptics | 1 SWS | Practice / 🗣 | Fernandez Corbaton, Rockstuhl |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

## T 7.58 Course: Theoretical Optics [T-PHYS-102278]

**Responsible:** PD Dr. Boris Narozhnyy
Prof. Dr. Carsten Rockstuhl
**Organisation:** KIT Department of Physics
**Part of:** M-PHYS-102280 - Theoretical Optics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 4 | Grade to a third | Each summer term | 1 |

| Exams | | | |
|---|---|---|---|
| ST 2024 | 7800133 | Theoretical Optics - Exam 1 | Rockstuhl |
| ST 2024 | 7800140 | Theoretical Optics - Exam 2 | Rockstuhl |

**Prerequisites**
Successful participation in the exercises

**Modeled Conditions**
The following conditions have to be fulfilled:

1. The course T-PHYS-102305 - Theoretical Optics - Unit must have been passed.

## T 7.59 Course: Theoretical Optics - Unit [T-PHYS-102305]

**Responsible:** PD Dr. Boris Narozhnyy
Prof. Dr. Carsten Rockstuhl

**Organisation:** KIT Department of Physics

**Part of:** M-PHYS-102280 - Theoretical Optics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Completed coursework | 0 | pass/fail | Each summer term | 1 |

| Events | | | | | |
|---|---|---|---|---|---|
| ST 2024 | 4023111 | Theoretical Optics | 2 SWS | Lecture / 🗣 | Rockstuhl |
| ST 2024 | 4023112 | Exercises to Theoretical Optics | 1 SWS | Practice / 🗣 | Rockstuhl, NN |
| **Exams** | | | | | |
| ST 2024 | 7800058 | Theoretical Optics - Unit | | | Rockstuhl |

Legend: 🖥 Online, ⚙ Blended (On-Site/Online), 🗣 On-Site, ✕ Cancelled

**Prerequisites**
none

## T 7.60 Course: X-Ray Optics [T-MACH-103624]

**Responsible:** Dr. Arndt Last
**Organisation:** KIT Department of Mechanical Engineering

**Part of:** M-MACH-101920 - X-Ray Optics

| Type | Credits | Grading scale | Recurrence | Version |
|---|---|---|---|---|
| Written examination | 3 | Grade to a third | Each term | 1 |

| Exams | | | |
|---|---|---|---|
| ST 2024 | 76-T-MACH-103624 | X-Ray Optics | Last |
| WT 24/25 | 76-T-MACH-103624 | X-Ray Optics | Korvink, Last |

**Competence Certificate**
oral exam

**Prerequisites**
none

Karlsruher Institut für Technologie

The Research University in the Helmholtz Association



# Official Announcement

**2019** **Published at Karlsruhe on July 19, 2019** **No. 35**

**Contents** **Page**

141

**Statutes for the Amendment of the Study and Examination Regulations of Karlsruhe Institute of Technology (KIT) Relating to the Master's Program "Optics & Photonics"**

of July 18, 2019

Pursuant to Article 10, par. 2, clause 5 and Article 20, par. 2, sentence 1 of the Act on Karlsruhe Institute of Technology (KIT Act – KITG) of July 14, 2009 (bulletin, pp. 317), last amended by Article 2 of the Act on the Further Development of the Higher Education Law (Gesetz zur Weiterentwicklung des Hochschulrechts – HRWeitEG) of March 13, 2018 (bulletin, p. 85, 94), and Article 32, par. 3, sentence 1 of the Law of Baden-Württemberg on Universities and Colleges (Landeshochschulgesetz – LHG) of January 1, 2005 (bulletin, pp. 1), last amended by Article 1 of the Act on the Further Development of the Higher Education Law (Gesetz zur Weiterentwicklung des Hochschulrechts – HRWeitEG) of March 13, 2018 (bulletin, p. 85), the Senate of KIT on July 15, 2019 adopted the following Statutes for the Amendment of the Study and Examination Regulations of Karlsruhe Institute of Technology (KIT) Relating to the Master's Program "Optics & Photonics" of August 4, 2015 (Official Announcement by Karlsruhe Institute of Technology (KIT) No. 64 of August 6, 2015).

The President expressed his approval on July 18, 2019 according to Article 20, par. 2, sentence 1 KITG and Article 32, par. 3, sentence 1 LHG.

**Article 1 – Amendment of the Study and Examination Regulations**

1. In the **Contents**, reference to "Article 26" shall be replaced by reference to "Article 25".
2. In **Article 9, sentence 1**, the words "or if a re-examination according to Article 8, par. 6 is not passed in due time" shall be deleted.
3. **Article 12, par. 1 shall be changed as follows:**

a) Sentence 1 shall be formulated as follows:

"The provisions of the Act for the Protection of Mothers at Work, in Education, and in Higher Education (Maternity Protection Act - MuSchG) in its respectively applicable version shall apply."

b) Sentence 2 shall be canceled.

c) Sentences 3 and 4 shall become sentences 2 and 3.

**Article 14 a, par. 2 shall be changed as follows:**

**a)** Sentence 2 and sentence 3 shall be canceled.

**b)** Sentence 4 shall become sentence 2.

5. **Article 16, par. 7 shall be changed as follows:**
   **a)** In **sentence 4**, the words "… to the Presidential Committee of KIT in writing or for record …" shall be replaced by the words "to the latter".

   **b)** A new sentence (**sentence 5**) shall be added: "Any objections shall be decided by the Vice President for Higher Education and Academic Affairs."

6. In **Article 17, par. 3**, the words following the word "if", i.e. "one of the KIT departments involved according to Art. 1, cl. 2 has granted them the authorization to examine and" shall be deleted.

7. In **Article 19, par. 3, sentence 2, second indent**, the words "Advanced Spectroscopy" shall be replaced by the words "Quantum Optics & Spectroscopy".

8. **Par. 5** shall be added to **Article 25**, as follows:

   To students who

   1. started their studies in the Master's program Optics & Photonics before winter semester 2019/2020 or
   2. begin their studies in the Master's program Optics & Photonics in a higher semester starting in the winter semester of 2019/2020, provided that the relevant semester is above the first-semester stage,

   Article 14 a, par. 2 and Article 19, par. 3, sentence 1, second indent in the version of the Study and Examination Regulations of Karlsruhe Institute of Technology (KIT) Relating to the Master's Program "Optics & Photonics" of August 4, 2015 (Official Announcement by KIT No. 64 of August 6, 2015) shall continue to apply.

   Students according to sentence 1, number 1 and number 2, may take the professional internship on the basis of Article 14 a, par. 2, and examinations on the basis of Article 19, par. 3, sentence 1, second indent of the Study and Examination Regulations of Karlsruhe Institute of Technology (KIT) Relating to the Master's Program Optics & Photonics in the version of August 4, 2015 (Official Announcement by KIT No. 64 of August 6, 2015) for the last time until the end of the examination period of the summer semester of 2022.

**Article 2 – Entry into Force**

This amendment will enter into force on October 1, 2019.

Karlsruhe, July 18, 2019

*Prof. Dr.-Ing. Holger Hanselka*
*(President)*

KIT – University of the State of Baden-Wuerttemberg and
National Research Center of the Helmholtz Association

# Official Announcement

2015 Published at Karlsruhe on August 06, 2015 No. 64

## Contents

Page



**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.**

**Study and Examination Regulations of Karlsruhe Institute of Technology (KIT) Relating to the Master's Program "Optics & Photonics"**

dated August 04, 2015

Pursuant to Article 10, par. 2, clause 5 and Article 20 of the Act on Karlsruhe Institute of Technology (KIT Act – KITG) of July 14, 2009 (bulletin, p. 317 f.), last amended by Article 5 of the Third Act on the Modification of University Regulations (3. Hochschulrechtsänderungsgesetz – 3. HRÄG) of April 01, 2014 (bulletin, pp. 99, 167), and Article 8, par. 5 of the Law of Baden-Württemberg on Universities and Colleges (Landeshochschulgesetz – LHG) of January 01, 2005 (bulletin, p. 1 f.), last amended by Article 1 of the Third Act on the Modification of University Regulations (3. HRÄG) of April 01, 2014 (bulletin, p. 99 ff.), the senate of KIT adopted the following Study and Examination Regulations Relating to the Master's Program "Optics & Photonics" on July 20, 2015.

The President expressed his approval on August 04, 2015 according to Article 20, par. 2 KITG and Article 32, par. 3, clause 1 LHG.

## Contents

**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 herewith 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.

**II. Master's Examination**

**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 certificate about the study and examination achievements made and the respective grades indicating that the examination has not been passed. The same shall apply when the entitlement to an examination has expired.

### 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)