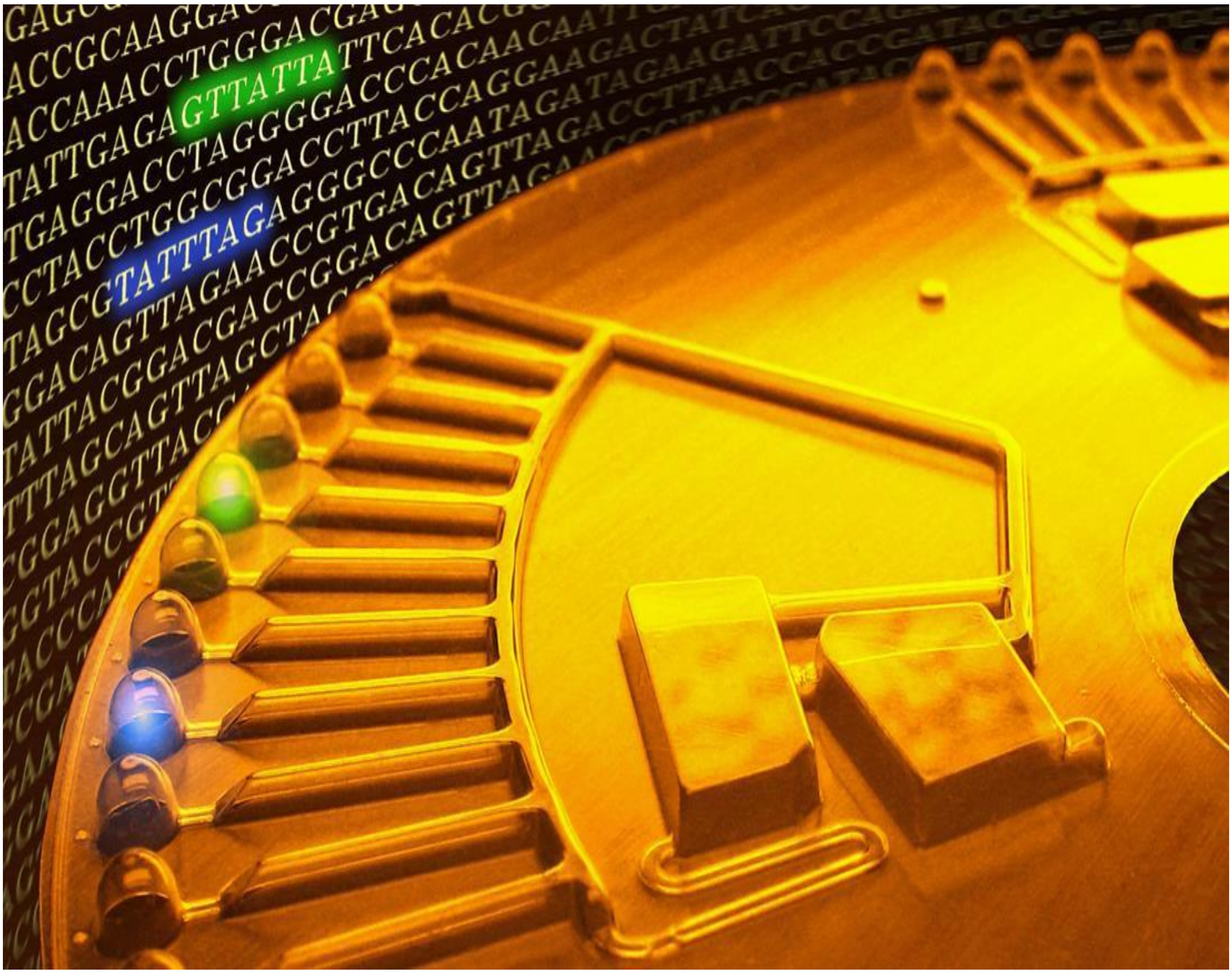
31.03. 2024

Master of Science (M. Sc.) *Microsystems Engineering*

Gemäß der Prüfungsordnung von 2021



Institut für Mikrosystemtechnik (IMTEK)
Technische Fakultät
Albert-Ludwigs-Universität Freiburg

universität freiburg

Content

THE MASTER'S PROGRAM

Overview

University	University of Freiburg (Albert-Ludwigs-Universität Freiburg)
Faculty	Faculty of Engineering
Institute	Department of Microsystems Engineering Institut für Mikrosystemtechnik, IMTEK
Subject	Microsystems Engineering (MSE)
Degree	Master of Science (M.Sc.)
Duration	4 semesters / 2 years, standard duration of studies
Type/Format	Consecutive, full-time studies on campus
ECTS	120 ECTS credits
Language(s)	English (no German skills necessary; however some elective modules are offered in German)
Profile	The Master of Science program MSE, is research-oriented and consecutive. It is designed for highly qualified national and international graduate students holding a bachelor's degree in engineering or science. The English-taught master's program provides in-depth engineering skills on circuits and systems as well as on materials and fabrication technologies. Application related fields of qualification are biomedical technology and photonics. Depending on the individual focus, students can acquire and deepen specific knowledge in these technical concentration areas.
Educational Goals/Professional Prospects	M.Sc. MSE students will have the opportunity to • be involved in state-of-the-art research with internationally renowned professors, • benefit from state-of-the-art equipment on a modern campus and pioneering laboratories at partner institutes, • benefit from a European campus (www.eucor-uni.org), • live in one of Germany's most appealing and green cities.

	Successful students will be enabled to explore, design and apply microsystem-based technical solutions during their subsequent employment as engineers. The accomplishment of the Master's degree qualifies for an academic career in research and development as well as for an engineering occupation in industry, in scientific or research organizations or in a state authority.
Admission Requirements	• A bachelor's degree in engineering or in science with a total of 180 ECTS and a duration of at least 3 years • An average grade of 2.9 or better on the German grading scale • Advanced English language skills at the level of CEFR C1 on the Common European Framework of Reference for Languages
Intake	Winter semester
Further information	www.imtek.uni-freiburg.de

Department / IMTEK

The Department of Microsystems Engineering IMTEK was founded in 1995. Presently, it has 21 professors, over 370 research, teaching, and technical staff, and 800 microsystems engineering students. Today we are one of the world's largest academic institutions in our field, and this is reflected in IMTEK's uniquely broad scope of research and courses. The main research focus areas are: Energy Autonomous Microsystems, Smart Systems Integration, Lab-on-a-Chip and Medical MEMS. With our scientific work we help to make life healthier, safer, more comfortable and versatile, and, not least, easier. We turn research ideas into reality by laying the foundations for better and more intelligent products based on micro- and nanotechnologies. We train young scientists to be microsystems engineers by teaching them how to pass on this visionary spirit and to make vision reality. IMTEK's output can be measured by the numbers of high-quality scientific publications, patents, innovative products, and successful start-ups coming from IMTEK. The research publications were cited 6607 times in 2018. This means that more than five scientific publications published worldwide every day refer to an IMTEK research publication.

Chairs at IMTEK

21 professors form IMTEK's backbone. Organised autonomously, they cover the whole variety of Micro-Technology**.** In alphabetical order, they are

Buse, Karsten	Optische Systeme
Dehé, Alfons	Georg H. Endress Professur für Smart Systems Integration
Daus, Alwin	Sensoren
Eberl, Christoph	Mikro- und Werkstoffmechanik
Egert, Ulrich	Biomikrotechnik
Kuhl, Matthias	Mikroelektronik
Milana, Edoardo	Soft Machines
Pastewka, Lars	Simulation
Paul, Oliver	Materialien der Mikrosystemtechnik
Rapp, Bastian	Prozesstechnologie
Rohrbach, Alexander	Bio- und Nanophotonik
Rupitsch, Stefan	Elektrische Messtechnik und Eingebettete Systeme
Rühe, Jürgen	Chemie und Physik von Grenzflächen
Stieglitz, Thomas	Biomedizinische Mikrotechnik

Wallrabe, Ulrike	Mikroaktorik
Wöllenstein, Jürgen	Gassensoren
Woias, Peter	Konstruktion von Mikrosystemen
Zappe, Hans	Gisela-und-Erwin-Sick-Professur für Mikrooptik
Zengerle, Roland	Anwendungsentwicklung
apl. Prof. Dr. Hanemann, Thomas	Werkstoffprozesstechnik
apl. Prof. Dr. von Stetten, Felix	Hahn-Schickard-Institut für Mikroanalysesysteme
Junior Research Groups	
Ataman, Caglar	Microsystems for Biomedical Imaging Lab Junior Reasearch Group Leader
Dincer, Can	Disposable Microsystems Junior Research Group Leader
Slesarenko, Viacheslav	MetaLab Research Group, Nachwuchsgruppenleiter
Vierrath, Severin	Elektrochemische Engergiesysteme Junior Reaserch Group Leader

Profile and Qualification Goals

In the Microsystems Engineering Master program it is the overall educational goal to graduate students to a post-graduate level where they can perform engineering tasks on a high scientific level. To that purpose they will gain expertise in concentration areas that will be described in the further chapters. On the path from an idea to a product the required professional skills will enable first for problem definition and then for subsequent solutions finding and evaluation. The development of micro-devices and systems will require methods of design, construction and simulation in mechanical, electrical, materials and physical domains. For the fabrication the advanced chemical, physical and mechanicals processes must be understood, utilized and controlled. Also characterization and testing are important in order to optimize on all levels of systems' architecture. In these fields the versed use of computers, algorithms and software is an indispensable capability.

On this basis, microsystems masters will be capable of engineering techniques and use them effectively on the way from research to the market. Besides technical expertise graduates also need non-technical skills like the ability to work in a team, social competence, creativity and openness to new ideas, communication skills. The program also promotes entrepreneurial thinking and the ability to motivate oneself.

The applications of Microsystems are manifold:

In Medicine there are trends towards, minimally-invasive surgery, advanced diagnostics or intelligent prostheses. Modern communications systems rely on optics or on radio frequencies like mobile phones. Networks and sensors become more and more ubiquitous for consumers. The same holds for industrial applications, process management and instrumentation. In automobiles modern by-wire controls, safety features or even autonomous functions are based on optical microsystems and micro-sensors. It appears impossible to provide the deepest knowledge in all related fields. Therefore, the program was designed in a way that engineers from related fields will be elevated to a postgraduate level on a standard knowledge platform of microsystems engineering. Starting from this basis a specialization in the mentioned fields will be possible.

Technical qualification goals

Students

- are able to analyse technical questions and to develop, design, test, optimize and manufacture microsystems
- acquire an overview of the most important methods, models, processes and technologies for realizing microsystems. They are able to select, apply and combine the processes and methods that are suitable for a given problem
- learn strategies for identifying and evaluating new applications of microsystems
- are able to prepare, plan, carry out and document experiments independently
- have an applicable overview of the most common design, fabrication and test techniques used in practice as well as their extensions and new methods
- acquire in-depth knowledge in a special field of microsystems engineering in the area of concentration or specialization they have chosen
- know how to address technical problems that require knowledge beyond the learning content of their studies

General qualification goals

Students

- are able to draw up a laboratory diary, write scientific reports, give a scientific lecture and create a scientific poster
- can work on a given technical question largely independently and document the result in a scientific paper
- are able to team up in project groups, which can be made up of students from different master's courses in the concentration modules, to promote social and intercultural competences

Peculiarities (international cooperation, studying abroad, internships)

In addition to the ERASMUS-Partnerships of the University, the Department of Microsystems Engineering has concluded a cooperation contracts with the following international Universities and institutes:

- ESIEE – Ecole Supérieure d'Ingénieurs en Electronique et Electotechnique, Noisy-le-Grand, Frankreich
- Technical University of Denmark (DTU), Lyngby, Dänemark
- College of Engineering, University of Michigan, USA
- Tohoku University, Graduate School of Engineering, Sendai, Japan
- University of Tokyo, Graduate School of Engineering, Tokyo, Japan
- Ritsumeikan University, Kusatsu, Japan
- Kyoto University, Graduate School of Engineering, Kyoto, Japan

Within this framework, Students have the opportunity to complete foreign semesters, in most cases without additional tuition fees.
There is no mandatory internship requested. We have observed, that international students

select to have elective internships in industry or to perform the work of their Master Thesis there. Most find such positions on their own initiative. Some seek professors' advice in order to get contacts and to improve their applications.

Examination Regulations and Module Handbook

The content and organization of studies are defined by the respective **Subject-Specific Examination Regulations** (*Prüfungsordnung*, PO) for each program and the **General Examination Regulations** (*Rahmenprüfungsordnung*). The latter provide the overarching regulatory framework of a certain degree, in our case all Master of Science programs at the University of Freiburg. One can find a German and English version on our website. The German version is the official version. The unofficial English version is legally non-binding and is just a courtesy translation.

This Module Handbook has been compiled according to the **Subject-Specific Examination Regulations: 2021** for the Master of Science *Microsystems Engineering*. These regulations define all formal and legal aspects of this specific study program. In case of the M.Sc. MSE Examination Regulations of 2021, the framework of the program is based on a compulsory area with five modules and an elective area that is primarily based on two sub-areas. One of these, the mandatory elective area **Advanced Microsystems** offers eight modules from which five (30 ECTS) have to be selected. Further 30 ECTS can be acquired in an **area of choice**. The four **Concentration Areas** *Circuits and Systems, Materials and Fabrication, Biomedical Engineering and Photonics* contain a range of elective modules. Furthermore, in a **Customized Course Selection Area** nine ECTS can be gained. The final module is the **Master's Module**. The four areas of concentration are also marked in this Module Handbook. The subsequent pages will provide detailed information about all areas and how to achieve the M.Sc. MSE degree. Students will be able to focus on their preferred concentration area from the very beginning. Several interdisciplinary modules can be selected to enhance their holistic societal and scientific understanding of a student.

A module is a self-contained unit within a scientific topic or an area that is defined by specific learning goals. Modules may consist of one or more courses. A course is the smallest unit described in this Module Handbook. There are different types of courses including lectures (Vorlesung), exercises (Übung), laboratory courses (Praktikum, Praktische Übung) and seminars. This Module Handbook describes the modules that constitute the curriculum of the MSE program. Individual module descriptions comprise elements such as title of the module, qualification goals, recommended requirements, course content, name of the offering institution & professor, type of assessment, and how many ECTS credits according to the *European Credit Transfer and Accumulation System* (ECTS) will be awarded to the student when completing the module successfully. These credits define the associated workload. For a representative student, one credit is equivalent to a workload of 30 hours. The recommended number of ECTS credits to be completed per term is 30. In this way, the ECTS credits define the weighting of a module within the entire master's program and its impact on the final overall grade, similar to the Grade Point Average, GPA.

Students of the master's program MSE have to complete 120 ECTS credits in total in order to earn their degree. This usually requires two years, organized in four terms (semester). The entire Faculty of Engineering has installed a uniform ECTS system. This means that a module or course has quantum size of 3, 6 or 9 ECTS credits. As it is possible to select elective modules from other master programs, this standardization makes intra-faculty studies that utilize the complete faculty much easier. Most of the courses offered for the MSE program by IMTEK are also open for other degree programs. All of the associated study programs are shown in **HISinOne**, the university's Campus Management System.

Teaching and Learning Methods

Lectures and the corresponding exercises make up the largest part of the modules and courses within the master's program MSE.
Almost all Mandatory Modules as well as the *Mandatory Elective Modules* offered within the four Concentration Areas *Circuits and Systems, Materials and Fabrication, Biomedical Engineering and Photonics* consist of a lecture and an exercise. These modules are open to all M.Sc. MSE students, and mostly to other study programs, thus reaching a participant number of up to 100 students or even more.
Within the *Elective Modules* offered within the Microsystems Concentration *Area* as well as in the *Customized Course Selection*, the knowledge transfer is carried out additionally in seminars, practical exercises, laboratory courses or even lecture series as well as partially in integrated project work. These modules are typically more interactive due to the smaller group sizes of approximately 25 – 30 students. For laboratory courses, the numbers of places for students are typically between 10 and 25.
Within the scope of the *Master's Thesis*, students can select an individual research topic defined by themselves or a professor. After the goal of an assigned topic has been agreed upon, the student will work independently in the IMTEK laboratory. Guided by the principal supervising professor, and in most cases by an additional academic supervisor they learn to solve scientific questions within a given timeframe, on the basis of capabilities acquired in the MSE program. The role of the 2nd official supervisor is mostly to consult and to perform a redundant evaluation of the master's thesis. If the student wishes, she/he can perform an external master thesis when certain conditions of supervision and quality control are met. Here external refers to a hosting organisation outside the IMTEK or even outside the university.

Assessment Types

Generally speaking, students can complete a module/course in two ways: with a *Prüfungsleistung* (PL) or a so-called *Studienleistung* (SL). Whether a course completes with a PL or SL is defined in the Subject-Specific Examination Regulations. It is further outlined in the framework and in the module descriptions on the subsequent pages.
A **Prüfungsleistung** (PL) is a graded assessment. So its grade(s) will count in the final overall grade. According to the §14 of the General Examination Regulations of the ALU, written Prüfungsleistungen are written supervised exams (*Klausuren*), open book exams or written reports (*schriftliche Ausarbeitungen*). Mündliche Prüfungsleistungen are oral exams (*Prüfungsgespräche*) or oral presentations. Praktische Prüfungsleistungen can consist of conducting and reporting experiments as well as of developing software programs or demonstrators. The duration of the written and oral assessments as well as the length of reports (e.g. number of pages) are usually defined in the module descriptions. Details are also provided by the lecturers in the respective courses in a timely manner. In general, a written PL can have a minimum duration of 60 minutes and a maximum of 240 minutes. An oral PL can have a duration between a minimum of 10 minutes and a maximum of 45 minutes.
A **Studienleistung** (SL) is a pass/fail assessment and must only be passed with a maximum grade of 4.0 on the German grading scale. These assessments do not count into the final overall grade, even if they are graded. §13 of the General Examination Regulations defines that "Studienleistungen are individual written, oral or practical assessments which need to be completed by students in conjunction with the module/course". They can take the form of active participation (85 % to 100 % mandatory attendance), completion of exercises or project work, written reports (e.g. protocols, posters), written exams, oral exams, oral presentations, conducting experiments, development of software programs or demonstrators.
In the elective Microsystems Engineering Concentration Areas every module is finalized with a

graded exam. in accordance with the concept of the respective course, the modules may also require non-graded exams. In several modules multiple partial exam completions are required. These must typically be produced during the lecture term. This helps to offer a higher number of exam types and it also decreases the workload during the examination period. Here, exam types are exercise sheets or reports, especially in laboratory classes. In laboratory courses, presence of the students can be obligatory, but alternative dates will be provided. In this way it is prevented that neither partial exams nor the compulsory attendance will increase the duration of study.
Studienleistungen (SL) and **Prüfungsleistungen** (PL) can be completed as online examinations, in accordance with the current examination regulations and framework regulations of the University of Freiburg.

Summary of assessments

- In addition to registering for a module, a student needs to register for every exam she/he wants to take.
- If failed, one can repeat every exam once. Two exams can be repeated twice.
- If one fails an exam, the student will automatically be registered for the retake in the following semester.
- One can only withdraw from an exam if one is ill or if there is an emergency in the family.

Framework

Program Structure, Specialisation and Concentration Areas

The master's program Microsystems Engineering is structured into a compulsory area and the two mandatory elective areas Advanced Microsystems and Microsystems Engineering Concentrations. The modules that can be selected in these areas as well as their corresponding courses are listed and described in the valid module handbook. When certain conditions are met, a specialization can be selected, that will be certified in the diploma.

In the compulsory area 60 ECTS credits have to be achieved. The area Advanced Microsystems requires additional 30 ECTS credits. Further 30 out of 60 ECTS credits of the mandatory elective area will be dedicated to Microsystems Engineering Concentration Areas. The student selects one of the four Concentration Areas *Circuits and Systems*, *Materials and Fabrication*, *Biomedical Engineering* and *Photonics* and finishes modules of his own choice from the course portfolio provided in the module handbook. So many can be chosen as one needs to accomplish a total of 30 ECTS credits. Of these a maximum of 9 credits can be acquired in the Customized Course Selection area. For that, suitable modules or courses from the curricula of other programs of the University of Freiburg can be attended. These comprise language courses and other courses from the curricula of the respective seminars and institutes.

This area can include Modules related to the Subject Area of MSE and Modules outside of the Subject Area. This is intended to enhance the students' holistic societal and scientific understanding. Within the Customized Course Selection area, students can complete up to 9 ECTS credits. Courses can be selected from the catalogue on the subsequent pages. All 9 ECTS credits can be assigned to Modules outside the Subject Area. Modules from the university wide course catalogue outside the Subject Area will be finalized just with a Studienleistung (SL, pass/fail assessment).

If one of the four areas Circuits and Systems, Materials and Fabrication, Biomedical Engineering or Photonics has been selected as the specialization for the diploma, modules with a total of at least 30 ECTS credits must be completed in that area. Also, the master thesis must have been assigned to the respective field. The degree awarded will be "Master of Science in Microsystems Engineering with Specialization in *Circuits and Systems* or *Materials and Fabrication* or *Biomedical Engineering* or *Photonics*.

While in the compulsory and in compulsory elective areas all modules exhibit a size of 6 ECTS credits, 60 % of the modules in the elective concentration areas are smaller, with a standard size of 3 ECTS credits. Although this complies not strictly with the respective order (Studienakkreditierungsverordnung), we see significant advantages: the offered course portfolio is much larger and very versatile. In this way, students have a higher flexibility in the module election and they can design their personal program very specific. Also, the respective students' feedback is generally positive.

All module grades are weighted with the same single factor in the computation of the final grade according to the Prüfungsordnung. Therefore, this fact is not mentioned in every module description.

Master's Section

The **Master's Section** with a total of 30 ECTS credits includes one mandatory module:

The Master's Module must be completed with a Prüfungsleistung (PL, graded assessment), and it consists of the master's thesis itself and the defence (27 + 3 ECTS credits). The defence is typically organized as a 20 minutes presentation plus 40 minutes of disputation.

Framework shown in a table

Table 1: Compulsory Area: All modules must be completed

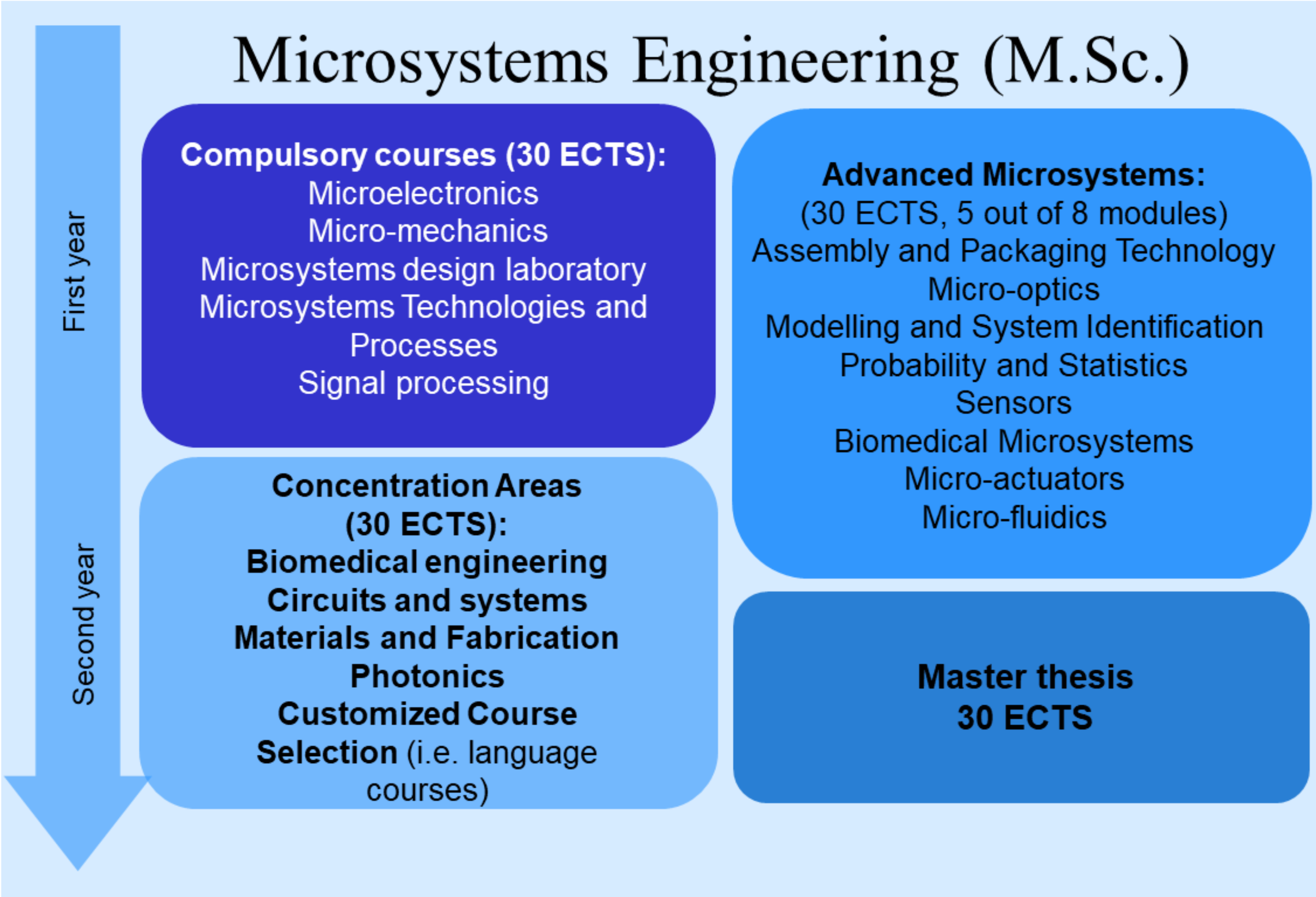
Module	Type	SWS	ECTS-credits	Semester	Studienleistung/ Prüfungsleistung
Micro-electronics	V + Ü	4	6	1	PL: Written exam
Micro-mechanics	V + Ü	4	6	1	PL: Written exam
MST Design Laboratory I for Microsystems Engineering	V + Ü	4	6	1	SL
MST Technologies and Processes	V + Ü	4	6	1	SL PL: Written exam
Signal Processing	V + Ü	4	6	2	PL: Written exam
Master's Module			30	4	PL: Master thesis PL: oral presentation

Tabelle 2: Elective mandatory area Advanced Microsystems (30 ECTS-Punkte)

Module	Type	SWS	ECTS-credits	Semester	Studienleistung/ Prüfungsleistung
Assembly and Packaging Technology	V + Ü	4	6	1, 2 or 3	PL: Written exam
Micro-optics	V + Ü	4	6	1 or 3	SL PL: Written exam
Modelling and System Identification	V + Ü	4	6	1 or 3	SL PL: Written exam
Probability and statistics	V + Ü	4	6	1 or 3	SL PL: Written exam
Sensors	V + Pr	4	6	1 or 3	SL PL: Written exam
Biomedical Microsystems	V + Ü	4	6	2	SL PL: Written exam
Micro-actuators	V + Ü	4	6	2	SL PL: Written exam
Micro-fluidics	V + Ü	4	6	2	PL: Written exam

Abbreviations:
PL=*Prüfungsleistung*/graded assessment; SL= *Studienleistung*/pass/fail assessment; V=*Vorlesung*/lecture; Ü=*Übung*/exercise; S=*Seminar*/seminar; Pr=*Praktikum*/practical exercise; SWS=*Semesterwochenstunden*/hours per week per semester; x=undefined, depends on the subject/module

Illustration of the Framework



Info: ECTS is a standard for comparing the study attainment and performance of students of higher education across the European Union and other collaborating European countries. For successfully completed studies in the master program *Microsystems Engineering* 120 ECTS credits are awarded. One ECTS credit equals on average 30 hours of workload.
For more Information, see the Subject-Specific and General Examination Regulations. Both set the legal framework for the studies. The available modules/courses are listed and described in detail in the Module Handbook.

STUDY ORGANIZATION

Course Information and Registration

The **Course Catalogue** (*Vorlesungsverzeichnis*) in **HISinOne,** the university's **Campus Management System** shows the offered courses and the corresponding modules for every semester. In addition, the course catalogue provides information on course registration/sign up procedures, important dates during the semester and the content of the respective courses. For an overview of all MSE-relevant courses we strongly recommend the use of the tool **Planner of Studies** (*Studienplaner*) in HISinOne. For further information see the step-by-step guide for the registration/sign up process.

All courses offered by IMTEK, INATECH or IIF, which are all institutes at the Faculty of Engineering, are available for registration in HISinOne. Usually there is no limitation of seats in compulsory and elective mandatory modules or courses. In some lectures as well as in laboratories in the elective area, there can be limits to capacity. The information on the maximum number of attendees and on the mode of granting access are found in the module description in HISinOne. The limited seats are in most cases allocated based first-come-first-serve-principle. Although there is no legal right to get a seat in a specific course or module, the teacher can be addressed for acceptance directly and will comply, when reasonable arguments are given.

If a course is not offered by IMTEK, it is the students' responsibility to look for further information about the course. Normally, all information about courses are given in HISinOne or on the respective websites of the faculties & chairs offering the courses. The different faculties and departments may have specific registration requirements, periods and procedures. It is important that students make sure that they will inform themselves in time and – if necessary – get in contact with these units. Some courses are not offered regularly.

For Modules outside the Subject Area within the Customized Course Selection area every student is welcome to select further courses from the extensive course catalogue offered by the University of Freiburg. However, before students register for new courses (new means not listed below), each course has to be checked regarding its suitability for the M.Sc. MSE master's program. This is done by the dean of academic affairs. Students must send an e-mail with all necessary information about their course of choice to the program coordinator studiengangkoordination.mst@imtek.uni-freiburg.de) at the latest by the semester start (April 1/October 1). The necessary information includes at least: course number, name, content outline of the course, ECTS credits, required Prüfungsleistung, required Studienleistung, link to further information, and if available, name of offering institution and/or contact person.

Examination Registration

In order to take a Prüfungsleistung and/or a Studienleistung, students must register the PL/SL through HISinOne within the registration periods. The deadlines for the registration (and de-registration) for exams, the modalities as well as the actual exam periods are listed on the website of the Faculty of Engineering. Please note, courses from other faculties may have different registration rules and periods. This refers to the ones within the Customized Course Selection area. Some Mandatory/Elective Modules require both a PL and SL. If this is the case, students need to register for both. The completion of the SL is not a requirement for the registration and completion of the PL. In theory, the SL and PL can be completed independently from each other. However, from a practical and study-efficient perspective it is highly recommended to complete both the SL and PL within the same semester, i.e. within the semester when the course is actually offered.

Repetition of Examinations

Prüfungsleistungen which are graded "not adequate" (5.0) or which are considered as "failed"can be repeated once. In addition, a maximum of two failed Prüfungsleistungen can be repeated twice. For further information and the modalities for improving the grade see the Subject-Specific Examination Regulations.

Studienleistungen can be repeated as many times as needed until they are passed.

MODULES DESCRIPTIONS in HISinOne

GLOSSARY

English	Deutsch
CONTENT OF THE LECTURE/EXERCISE	Inhalt der Veranstaltung/Übung
DURATION	Moduldauer
ECTS CREDITS	ECTS-Punkte
FORMAT	Zugehörige Lehrveranstaltung
INSTITUTION	Einrichtung
LANGUAGE	Sprache
QUALIFICATION GOALS	Lernziele
LECTURER	Lehrperson
LITERATURE	Literatur
MANDATORY REQUIREMENTS	Zwingende Voraussetzungen
MODULE	Modul
MODULE RESPONSIBLE	Modulverantwortlicher
NUMBER	Nummer
PRÜFUNGSLEISTUNG (GRADED ASSESSMENT)	Prüfungsleistung (zählt in die Endnote)
RECOMMENDED REQUIREMENTS	Empfohlene Voraussetzungen
RECOMMENDED TERM	Empfohlenes Fachsemester
SEMESTER WEEK HOURS	Semesterwochenstunden
STUDIENLEISTUNG (PASS/FAIL ASSESSMENT)	Studienleistung (zählt nicht in die Endnote)
TERM CYCLE	Angebotsfrequenz
TYPE	Modultyp
WORKLOAD	Arbeitsaufwand

Technische Fakultät

Module description

Master of Science (M.Sc.) in the subject Microsystems Engineering
- Hauptfach
(Examination regulations version 2021)

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Table of Contents

Prolog

This module handbook is based on the upcoming version of the examination regulations for the Master of Science degree program in the 2021 version, subject-specific provisions for the major in Microsystems Engineering. These provisions define the course content structured in the modules and the curriculum structured in terms of semesters and areas.

Modules consist of different elements: Courses (e.g. lectures, exercises, seminars, etc.) and coursework (pass/fail assessments) or examinations (graded assessments). The module descriptions explain in more detail both the course elements and the required coursework and examinations to demonstrate the acquisition of competencies.In each case, the regular course and examination assessments are described; should it become necessary to deviate from the described assessments at short notice due to unforeseen circumstances, the substitute assessments will be announced in the first week of the lecture period at the latest.

For successfully completed modules, credit points are awarded, the so-called ECTS credit points according to the "European Credit Transfer and Accumulation System". These credits indicate the weighting of a course in a module as well as the workload associated with the course. One credit point corresponds to an effort of approx. 30 working hours per semester for an average student. A student should collect approx. 30 ECTS credits per semester.

The standard period of study is four semesters. A total of 120 ECTS points must be acquired in the Master of Science Microsystems Engineering.

Regulations regarding attendance: Attendance is not mandatory in lectures.Seminars and lab courses require regular attendance as part of the Studienleistung (pass/fail assessment) because it is essential for reaching the learning targets of these courses. Exercises may require regular attendance as well, in which case this fact will be stated in the description of the specific module.

While there are generally no admission requirements for examinations within a module, in the case of elective modules, it happens in very rare cases that two modules build directly on each other in terms of content and the corresponding advanced module can therefore only be completed if the introductory module has been successfully completed beforehand. This is indicated accordingly in the module descriptions.
Further information on the program (e.g. the examination regulations, the model study plan, entry requirements, etc.) can soon be found at https://www.tf.uni-freiburg.de/en/study-programs/microsystem-engineering/m-sc-microsystems-engineering

Name of node	Number of node
Master of Science in Microsystems Engineering PO 2021	11LE50K-T-9000-MSc-986-2021
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	

↑

Name of module	**Number of module**
Master's Modul	11LE50MO-9991-MSc-986-2021
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Faculty	
Technische Fakultät	

ECTS-Points	30.0
Workload	
Recommended semester	4
Duration	
Pflicht/Wahlpflicht (P/WP)	Pflicht
Frequency	in jedem Semester

Compulsory requirement

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload

Qualification
Mit erfolgreichem Bestehen des Mastermoduls hat der Studierende gezeigt, dass er/sie in der Lage ist, innerhalb einer vorgegebenen Frist eine gegebene Problemstellung aus Microsystems Engineering zu bearbeiten. In der Abschlussarbeit sind im Studium erworbene Kenntnisse und Fertigkeiten des/der Studierenden nach dem neusten Forschungsstand erkennbar angewendet worden. Der/Die Studierende hat in angemessener Weise seine/ihre Fach-, Methoden-, Forschungs- und Entwicklungskompetenzen eingesetzt und die Befähigung zur wissenschaftlichen Arbeit und Dokumentation nachgewiesen.

↑

Name of node	**Number of node**
Pflichtbereich / Mandatory Modules M.Sc. Microsystems Engineering (PO 2021)	11LE50KO-P-MSc-986-2021
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

Comment
In the mandatory area, students have to complete the following five modules and the Master's module (all together 60 ECTS points).

↑

Name of module	Number of module
Micro-electronics	11LE50MO-7050/986 PO 2021
Responsible	
Dr.-Ing. Matthias Keller Prof. Dr.-Ing. Matthias Kuhl	
Organizer	
Institut für Mikrosystemtechnik Mikroelektronik	
Faculty	
Institut für Mikrosystemtechnik Mechanische Werkstatt	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	1
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Pflicht
Frequency	nur im Wintersemester

Compulsory requirement

keine

Recommended requirement

Basic knowledge in electrical engineering and good knowledge in electronics, particularly with regard to the following topics:
- semiconductor diode
- bipolar transistor
- MOS transistor
- operational amplifier
- digital circuit design
- logic gates & logic families
- sequential circuits

Assigned Courses

Name	Type	P/WP	ECTS	HoW	Workload
Micro-electronics	Vorlesung		6.0	2.0	workload: 180 hours
Micro-electronics	Übung			2.0	

Qualification

Having attended the module, the students will be able to understand and to design widely used basic analog integrated circuits like current mirrors and differential amplifiers. The students understand the physical principles and the use of MOS transistors in circuits and are able to build simple circuits. Furthermore, they will be able to analyze microelectronic systems on block and on transistor level.

Examination achievement

written examination with a duration of 120 minutes

Course achievement
none
Usability
Mandatory module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021)

↑

Name of module	Number of module
Micro-electronics	11LE50MO-7050/986 PO 2021
Veranstaltung	
Micro-electronics	
Event type	Number
Vorlesung	11LE50V-7050/986
Organizer	
Institut für Mikrosystemtechnik Mikroelektronik	

ECTS-Points	6.0
Workload	workload: 180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
This course covers the fundamentals of microelectronics for analog circuits. It starts with a review of the CMOS process and the available components. Then, current sources, single stage amplifiers and differential amplifiers are discussed in time and frequency domain. The presentation of basic circuit concepts and their enhancements is completed with an introduction into analog circuit layout and a discussion of electronic noise in circuits. At last, applications of the presented circuits are shown, with a special focus on MEMS sensor readout. List of contents: 1. Introduction and review of CMOS technology and available components 2. Small signal equivalent circuit 3. Current sources 4. Single stage amplifier and its frequency behavior 5. Differential amplifiers 6. Noise in electronic circuits 7. Analog layout 8. MEMS Applications
Examination achievement
see module details
Course achievement
none
Literature
1. Allen, Holberg: CMOS Analog Circuit Design, Oxford University Press 2. Sedra, Smith: Microelectronic Circuits, Oxford University Press 3. Razavi: Design of Analog CMOS Integrated Circuits, McGraw-Hill Higher Education

Compulsory requirement
none
Recommended requirement
Basic knowledge in electrical engineering and good knowledge in electronics, particularly with regard to the following topics: ■ semiconductor diode ■ bipolar transistor ■ MOS transistor ■ operational amplifier ■ digital circuit design ■ logic gates & logic families ■ sequential circuits

↑

Name of module	**Number of module**
Micro-electronics	11LE50MO-7050/986 PO 2021
Veranstaltung	
Micro-electronics	
Event type	Number
Übung	11LE50Ü-7050/986
Organizer	
Institut für Mikrosystemtechnik Mikroelektronik	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercise helps to reinforce the teaching contents of the lecture.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none

↑

Name of module	Number of module
Micromechanics	11LE50MO-7100/986 PO 2021
Responsible	
Prof. Dr. Lars Pastewka	
Organizer	
Institut für Mikrosystemtechnik Simulation	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	1
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Pflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
Participants of this module have knowledge in mathematical analysis and linear algebra (basic calculus, vector operations, matrices, tensors, …) and basic physics (forces, momenta, …).

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Micromechanics	Vorlesung		6.0	2.0	workload 180 hours
Micromechanics	Übung			2.0	

Qualification
The student... ...understands the relationship between displacement, strain and strain energy density. ...can formulate and solve the equations for static force equilibrium of rigid and elastically deformable bodies.
Examination achievement
The final examination will be written and of 150 minutes duration.
Course achievement
none

Usability
Mandatory module for students of the study program ■ M.Sc.Microsystems Engineering (PO 2021)

↑

Name of module	Number of module
Micromechanics	11LE50MO-7100/986 PO 2021
Veranstaltung	
Micromechanics	
Event type	Number
Vorlesung	11LE50V-7100/986
Organizer	
Institut für Mikrosystemtechnik Simulation	

ECTS-Points	6.0
Workload	workload 180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

This course is an introduction into the mechanics of structures and materials with a focus on mechanics at small scales. The lecture contains:

- Statics: force systems, force couples, moments, bearings, internal force variables, free body diagrams, distributed loads
- Elastostatics: stress, force equilibrium, stress invariants, displacement, strain, Hooke's law, strain energy, compatibility, plane problems, Airy stress function, Westergaard stress function
- Beams & Plates: Euler-Bernoulli beam theory, buckling of beams, Kirchhoff plate theory
- Failure & Cracks: yield criteria, fracture modes, near-field solution, fracture toughness, strain energy release rate, Griffith criterion

Examination achievement

see module details

Course achievement

see module details

Literature

J.R. Barber, “Elasticity”, Kluwer Academic Publishers, 2012

P.C. Chou, N.J. Pagano, “Elasticity: Tensor, Dyadic, and Engineering Approaches”, Dover, 1992

D. Gross, W. Hauger, J. Schröder, W.A. Wall, J. Bonet, “Engineering Mechanics 2: Mechanics of Materials”, Springer, 2011

D. Gross, T. Seelig, “Fracture Mechanics: With an Introduction to Micromechanics”, Springer, 2017

L.D. Landau, L.P. Pitaevskii, A.M. Kosevich, E.M. Lifshitz, "Theory of Elasticity", Butterworth-Heinemann, 1986 J.L. Meriam, L.G. Kraige, "Engineering Mechanics: Statics", John Wiley & Sons, 2014 S.P. Timoshenko, J.N. Goodier, "Theory of Elasticity", McGraw Hill, 1987
Compulsory requirement
none
Recommended requirement
Participants of this module have knowledge in mathematical analysis and linear algebra (basic calculus, vector operations, matrices, tensors, …) and basic physics (forces, momenta, …).

↑

Name of module	**Number of module**
Micromechanics	11LE50MO-7100/986 PO 2021
Veranstaltung	
Micromechanics	
Event type	Number
Übung	11LE50Ü-7100/986
Organizer	
Institut für Mikrosystemtechnik Simulation Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercises will practice the contents of the lecture with sample problems. The lectures largely introduce the theoretical framework of mechanics analysis, while the exercise provides students the opportunity to engage with applied problems. Due to limitations in both lecture and exercise time, however, it is strongly recommended that students practice problems on their own as well. Exercise problems will not be graded or count toward the final course grade. Exercise problems will give students practice in utilizing and synthesizing multiple concepts in solving practical problems.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none

↑

Name of module	**Number of module**
MST Design Lab I for Microsystems Engineering	11LE50MO-7003 PO 2021
Responsible	
Prof. Dr. Peter Woias	
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	1
Duration	1 term
Pflicht/Wahlpflicht (P/WP)	Pflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
MST Design Lab I for Microsystems Engineering	Vorlesung		6.0	2.0	180 hours
MST Design Lab I for Microsystems Engineering - Praktische Übung	Praktikum			2.0	

Qualification
The MST Design Lab I is composed from a lecture and an associated lab course. This module is considered as an introduction into the essentials of product design, with a focus towards microsystems. The students shall learn the following topics: "What is product design, what are the suitable strategies for this endeavour?" and "What methodical or technical tools are available for product design, how are they used in the most efficient way?" Tools and strategies are content of the lecture. In the lab course the students will work in groups as virtual start-up companies, to find a product idea, design the product, make a specification sheet for the same and design a working technical solution. All work is done is done virtually, using methodical tools, mathematical models and calculations.
Examination achievement
none

Course achievement
The following deliveries have to be handed in or done at the end of the semester, and will be the basis for grading: A written report, comprising of tasks 1 to 3: Task 1: Specification sheet and market study for your product idea Task 2: Analysis of the specification sheet, solution concept, functional analysis Task 3: mathematical prove of feasibility, budget calculations An oral presentation of the project results (Task 4), together with a hand-in of the presentation material
Usability
Mandatory module for students of the study program ■ M.Sc.Microsytems Engineering (PO 2021)

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Name of module	**Number of module**
MST Design Lab I for Microsystems Engineering	11LE50MO-7003 PO 2021
Veranstaltung	
MST Design Lab I for Microsystems Engineering	
Event type	Number
Vorlesung	11LE50V-7003_PO 20091
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
In the lecture the 4-phase model of product design is treated. Together with the four phases, appropriate desing tools are presented and trained in conjunction with the associated lab course. Contents of the lecture are as follows: • Introduction: What is product design? • Product planning and situation analysis • Product search strategies • Specification sheets • Abstraction of specification sheets and functional principles • Creativity techniques • Rapid prototyping • Intellectual property protection by patents • Technical knowledge related to the proposed product application area
Examination achievement
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
MST Design Lab I for Microsystems Engineering	11LE50MO-7003 PO 2021
Veranstaltung	
MST Design Lab I for Microsystems Engineering - Praktische Übung	
Event type	Number
Praktikum	11LE50prÜ-7003_PO 20091
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
In the lab course product design is exercised by the students themselves, working in groups as virtual start-up companies. Their task is to find an innovative product idea, evaluate the potential market for their product, put together a specification sheet, evaluate the same and find a viable technical solution for their product idea. At the end of the semester all groups present their project in an oral presentation.
Examination achievement
Course achievement
see module details
Compulsory requirement
keine

↑

Name of module	**Number of module**
MST technologies and processes	11LE50MO-7250 PO 2021
Responsible	
Prof. Dr. Claas Müller Prof. Dr.-Ing. Bastian Rapp	
Organizer	
Institut für Mikrosystemtechnik Prozesstechnologie	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 Stunden
Recommended semester	1
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Pflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
MST technologies and processes	Vorlesung		6.0	2.0	180 hours
MST technologies and processes	Übung			1.0	

Qualification

It is the learning target that students will have a sound understanding of the fundamentals of MEMS technologies. They will know

- the physical and technological background of microsystems processing
- process flows for the fabrication of MEMS elements
- principals of material sciences (silicon and other semiconductors)
- principals of clean-room and vacuum technologies

Also the students will be able to apply this knowledge practically to own designs, and especially in the MST design laboratories.

Examination achievement

Written examination with a duration of 120 minutes

Course achievement

Within the practical course of this lecture, students will be assembled in teams and given an assignment to perform. The assignment will stem from the context of the lecture and will be solved by the teams independently under supervision of the professor. The assignment will be documented in a 4-page summary reported which will be graded and corrected. The result will then be presented in a 10-15 minute presentation.

Literature
Marc Madou: Fundamentals of Microfabrication and Nanotechnology, CRC Press; 3 edition (August 1, 2011), ISBN 978-0849331800 Menz, Mohr, Paul: Microsystem Technology, Wiley-VCH Verlag GmbH & Co. KGaA; Edition: 1 edition (February 15, 2001), ISBN 978-3527296347

Usability
Mandatory module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021) Compulsory elective module for students of the study program ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	Number of module
MST technologies and processes	11LE50MO-7250 PO 2021
Veranstaltung	
MST technologies and processes	
Event type	Number
Vorlesung	11LE50V-7250
Organizer	
Institut für Mikrosystemtechnik Prozesstechnologie	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	1
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The content of the course:

- overview of MEMS processing (silicon, polymers)
- mechanical, chemical and physical properties of silicon
- cleanrooms – layout, function and operational procedures
- lithographic methods: physical background, optical lithography, ebeam lithography, x-Ray lithography
- vacuum technology, thin film and etching processes: physical and chemical background, Oxidation, Doping, Implantation, Physical Vapor Deposition (PVD), Chemical Vapor Deposition (CVD), Chemical etching processes. Plasma and reactive ion etching (RIE)
- surface and bulk micromachinig (process chains)
- back end processing: wafer bonding, dicing
- assembly and packaging

Examination achievement

see module details

Course achievement

see module details

Literature

Marc Madou: Fundamentals of Microfabrication and Nanotechnology, CRC Press; 3 edition (August 1, 2011), ISBN 978-0849331800
Menz, Mohr, Paul: Microsystem Technology, Wiley-VCH Verlag GmbH & Co. KGaA; Edition: 1 edition (February 15, 2001), ISBN 978-3527296347

Compulsory requirement

none

Recommended requirement
none

↑

Name of module	**Number of module**
MST technologies and processes	11LE50MO-7250 PO 2021
Veranstaltung	
MST technologies and processes	
Event type	Number
Übung	11LE50Ü-7250
Organizer	
Institut für Mikrosystemtechnik Prozesstechnologie	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
keine

↑

Name of module	**Number of module**
Signal processing	11LE50MO-7400 PO 2021
Responsible	
Prof. Dr. Stefan Rupitsch	
Organizer	
Institut für Mikrosystemtechnik Elektr. Messt. u. Eingebettete Sys.	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Pflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
Good knowledge in mathematics (complex numbers, trigonometry, calculus, linear algebra, circuit analysis, differential equations).

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Signal processing - Vorlesung	Vorlesung		6.0	2.0	180 hours
Signal processing - Übung	Übung			1.0	

Qualification
With this module students will be able to mathematically model the propagation of signals in electronic systems, enabling them to optimize their design. In particular, students will be able to design and test analog and digital filters.
Examination achievement
Written exam (Klausur), 120 minutes
Course achievement
none

Usability
Mandatory Module for students of the study program ■ Master of Science in Microsystems Engineering (PO 2021)   Compulsory elective module for students of the study program ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), Wahlpflichtbereich, Bereich Mikrosystemtechnik ■ Master of Science in Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme

↑

Name of module	Number of module
Signal processing	11LE50MO-7400 PO 2021
Veranstaltung	
Signal processing - Vorlesung	
Event type	Number
Vorlesung	11LE50V-7400
Organizer	
Institut für Mikrosystemtechnik Elektr. Messt. u. Eingebettete Sys.	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The purpose of the course is to teach students how to mathematically model the propagation of signals through electrical systems. The following topics will be covered in the course:
Matlab, Analog networks, Network analysis, Convolution, Impulse response, Signal response, Freq response, Bode plot, Phasors, Transfer functions, Pole-zero plot, System response, Stability, Laplace transform, Analog Filter design, Sampling, Quantizing, Analog to digital converter, Digital to analog converter, Digital networks, Z transform, Digital filter design, Digital signal processor, Fourier series, Fourier transform, Discrete Fourier transform, Fast Fourier transform, and Windowing.

Examination achievement

see module details

Course achievement

see module details

Literature

In English:
- Denbigh, Philip: System Analysis and Signal Processing
- Mertins: Signal Analysis
- Mitra: Digital Signal Processing
- Kay: Fundamentals of statistical signal processing & Modern spectral estimation
- Ingle, Proakis: Digital Signal Processing using MATLAB

In German:
- Butz, Tilman: Fouriertransformation für Fußgänger
- Daniel Ch. von Grüningen: Digitale Signalverarbeitung, Fachbuchverlag Leipzig
- E. Schrüfer: Signalverarbeitung, Hanser Verlag
- R. Scheithauer: Signale und Systeme, Teubner Stuttgart
- Kammeyer, Kroschel: Digitale Signalverarbeitung
- Einführung in MATLAB, Skript zu den Übungen Signalverarbeitung SS2005

- Vorlesungsskript Signalverarbeitung SS2005
- Oppenheim, Schafer: Zeitdiskrete Signalverarbeitung

Compulsory requirement
None
Recommended requirement
Good knowledge in mathematics (complex numbers, trigonometry, calculus, linear algebra, circuit analysis, differential equations).

↑

Name of module	**Number of module**
Signal processing	11LE50MO-7400 PO 2021
Veranstaltung	
Signal processing - Übung	
Event type	Number
Übung	11LE50Ü-7400
Organizer	
Institut für Mikrosystemtechnik Elektr. Messt. u. Eingebettete Sys.	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see lecture
Course achievement
none
Compulsory requirement
None
Recommended requirement
Good knowledge in mathematics (complex numbers, trigonometry, calculus, linear algebra, circuit analysis, differential equations).

↑

Name of node	**Number of node**
Wahlpflichtbereich / Elective Modules Microsystems Engineering PO 2021	11LE50KO-WP-MSc-986-2021
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

Comment
In the elective area students have to complete 60 ECTS points. The elective area is divided into two sub-areas: Advanced Microsystems (30 ECTS) and Microsystems Engineering Concentration Areas (30 ECTS).

↑

Name of node	**Number of node**
Advanced Microsystems	11LE50KO-WP-MSc-986-2021 WP1
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

Comment
In the area Advanced Microsystems, students have to complete 30 ECTS points by choosing 5 of the following modules.

↑

Name of module	**Number of module**
Assembly and packaging technology	11LE50MO-7700/986 PO 2021
Responsible	
Prof. Dr. Jürgen Wilde	
Organizer	
Institut für Mikrosystemtechnik Aufbau- u. Verbindungstechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 Stunden
Recommended semester	2
Duration	
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Assembly and packaging technology	Vorlesung		6.0	2.0	180 hours
Assembly and packaging technology	Übung			1.0	

Qualification
Using the example of packaging and interconnection technology, the realization step from basically functioning microsystems to industrial products is demonstrated. In addition, an overview is given of the main technologies that are frequently used for the realization of demonstrators within the scope of the master's thesis. AVT is a complex technology that serves to generate the hardware of electronic systems. This technology draws directly from materials science, manufacturing technology, engineering mechanics and also electrical engineering. The aim of this module is to build operationally higher integrated systems by integrating and contacting a functional element and at the same time providing a barrier to protect it from environmental influences. The main learning objective is to understand the manufacturing technologies for electronic hardware and specifically for microsystems using modern industrial manufacturing processes. Another important learning objective is the knowledge of the concepts for the design and optimization of the assembly and interconnection technology in microsystems technology, taking into account functionality, service life, stress and operating conditions, and the ability to apply them to one's own scientific questions. The learning objective is also to qualify students specifically for the practical questions on assembly and interconnection technology that frequently arise during the master's thesis.

Examination achievement
written examination (150 minutes)
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Advanced Microsystems

↑

Name of module	Number of module
Assembly and packaging technology	11LE50MO-7700/986 PO 2021
Veranstaltung	
Assembly and packaging technology	
Event type	Number
Vorlesung	11LE50V-7700/986_2018

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Assembly and packaging comprises a complex technology which aims at the fabrication of electronic hardware. This technology is mainly based on Materials Science and Engineering, Mechanical and Electrical Engineering. The target is to connect a functional element to an application and at the same time to protect it from the environment.
Fabrication technologies comprise assembly, joining and interconnection, while the main constructional elements are substrates, housings or packages. For all of these present days' state of the art is presented and the fundamental requirements are demonstrated. So the students will get an overview of the basic manufacturing operations and the required materials in order to integrate electronic hardware.
Besides, it is indispensable that knowledge about modern techniques for design optimisation will be taught. Electronic systems must fulfil specifications concerning integration density, high frequency behaviour, thermal management, thermal-mechanical behaviour and lifetime. To that purpose, the basic techniques for performance and reliability optimization will be regarded. In this way, it is desired that the students will become capable of finding own solutions in the field of assembly and packaging of microsystems.
The course comprises the following

1. Housing and packaging technologies - Hermetic and plastic packaging, wafer-level packaging
2. Substrates - Printed circuit boards, multi-chip-modules, moulded interconnect devices
3. Assembly technologies - Surface mount technology, adhesive bonding
4. Interconnection technology - Wire bonding, flip-chip-bonding
5. Electromagnetic compatibility EMC -Integrity and speed of electrical signals and equivalent circuits
6. Thermal management -Temperature problems and cooling techniques
7. Mechanical optimization -Stress-affected problems, solder joint reliability

Examination achievement

see module details

Course achievement

none

Literature

- An English manuscript will be made available in printed and in electronic form. Sources of information and references for the various fields are given in the manuscript.

Compulsory requirement
none
Recommended requirement
none

↑

Name of module	Number of module
Assembly and packaging technology	11LE50MO-7700/986 PO 2021
Veranstaltung	
Assembly and packaging technology	
Event type	Number
Übung	11LE50Ü-7700/986_2018

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercise helps to reinforce the teaching contents of the lecture. It is the aim that students will be enabled to apply the acquired competences to relevant applications of assembly, packaging and interconnection technology like power electronics or sensor systems. To that purpose specific tasks will be exercised, which help to create suitable application-specific packaging concepts. Also it will be important to select the corresponding materials and fabrication processes properly. A highly relevant aspect is the capability to evaluate assembly and packaging concepts quantitatively with respect to the relevant performance parameters. Such criteria comprise a signal's time-of-flight, the thermal resistance, stress level, and life-time.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
keine

↑

Name of module	Number of module
Micro-optics	11LE50MO-7600/986 PO 2021
Responsible	
Prof. Dr. Hans Zappe	
Organizer	
Institut für Mikrosystemtechnik Mikrooptik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	1
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Micro-optics	Vorlesung		6.0	2.0	180 hours
Micro-optics	Übung			2.0	

Qualification

Optics is the science and engineering of light and is one of the most important technical disciplines with wide-ranging applications in both basic science and in industrial application.
Micro-optics is optics for microsystems, small-scale components and systems which bring light into MEMS. This course will introduce the physics of light, the concepts of optics and optical components and their use in a broad variety of microsystems.

The instructional aim of the course Micro-optics is the establishment of competence in basic optics, including optical components and systems, and generation of the ability to incorporate optical concepts into MEMS.

At the completion of the course, the successful student should possess:

- a basic understanding of electromagnetic radiation and its interaction with matter;
- the ability to analyze and understand the most important optical components and their functionality;
- expertise in the analysis of fundamental lens combinations;
- the ability to design and calculate the behavior of simple optical systems;
- an awareness of the most important fabrication and assembly processes used in optics;
- the ability to understand and apply micro-optical components and concepts in microsystems.

Examination achievement
Written examination with a duration of 120 minutes
Course achievement
There are exercises at regular intervals that have to be worked on and handed in. These are corrected and assessed with points. The course work has been passed if at least 50% of the exercise sheets have been prepared and submitted as well as if 50% of the practice sessions were attended.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Advanced Microsystems

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Name of module	**Number of module**
Micro-optics	11LE50MO-7600/986 PO 2021
Veranstaltung	
Micro-optics	
Event type	Number
Vorlesung	11LE50V-7600/986
Organizer	
Institut für Mikrosystemtechnik Mikrooptik	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

This course covers the fundamentals of micro-optics with a focus on implementation and application in optical microsystems. Following an overview of the relevant basic mathematics and electromagnetics, we will consider optical phenomena including Gaussian optics, optical interfaces and materials. The core of the course consists of an in-depth presentation of reflective, geometric, diffractive and integrated optics. In each section, both the basic optical components as well as their application in microsystems are considered.

Table of contents:

1. Electromagnetic waves
2. Light waves & beams
3. Optical materials
4. Optical interfaces
5. Reflective optics
6. Refractive optics
7. Refractive components
8. Refractive systems
9. Diffractive optics
10. Diffractive components
11. Waveguide optics
12. Fiber optics
13. Fabrication

Examination achievement

see module details

Course achievement
see module details
Literature
English: • H. Zappe: Fundamentals of Micro-optics • E. Hecht: Optics • R. Hunsperger: Integrated Optics • B. Saleh & M. Teich: Fundamentals of Photonics • S. Sinzinger & J. Jahns: Microoptics • W. Smith: Modern Optical Engineering • H. Zappe: Introduction to Semiconductor Integrated Optics In German: • E. Hecht: Optik • G. Litfin: Technische Optik in der Praxis
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Micro-optics	11LE50MO-7600/986 PO 2021
Veranstaltung	
Micro-optics	
Event type	Number
Übung	11LE50Ü-7600/986
Organizer	
Institut für Mikrosystemtechnik Mikrooptik	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercises serve to deepen the learning material in micro-optics.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Modelling and System Identification	11LE50MO-2080 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine | none
Recommended requirement
fundamental knowledge in higher mathematics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Modellbildung und Systemidentifikation / Modelling and System Identification	Vorlesung		6.0	2.0	180 hours
Modellbildung und Systemidentifikation / Modelling and System Identification	Übung			2.0	

Qualification
Aim of the module is to enable the students to create and identify models that help to describe and predict the behaviour of dynamic systems. In particular, students shall become able to use input-output measurement data in form of time series to identify unknown system parameters and to assess the validity and accuracy of the obtained models.
Examination achievement
Written exam (180 minutes)

Course achievement
The course work is successfully completed if both of the following criteria are met: 1) Passing the exercise: For each exercise sheet, the achieved points are determined in percentage points with respect to the maximum score of the respective exercise sheet. The two exercise sheets with the lowest percentage points achieved will not be included in the assessment. The exercise is considered passed if the average of the achieved percentage points in the remaining exercise sheets is at least 50 percentage points. 2) Passing the micro-examinations: For each micro-examination, the points achieved are determined in percentage points with respect to the maximum number of points. The micro-exam in which the fewest percentage points were obtained will not be included in the evaluation. The microclauses are considered passed if the average of the percentage points achieved in the remaining microclauses is at least 50 percentage points.

Usability
As compulsory elective in ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Advanced Microsystems Engineering ■ M.Sc. Microsystems Engineering (PO 2021) in Advanced Microsystems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021)

↑

Name of module	**Number of module**
Modelling and System Identification	11LE50MO-2080 PO 2021
Veranstaltung	
Modellbildung und Systemidentifikation / Modelling and System Identification	
Event type	Number
Vorlesung	11LE50V-2080
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	6.0
Workload	180 hours
Attendance	60 hours
Independent study	120 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Linear and Nonlinear Least Squares, Maximum Likelihood and Bayesian Estimation, Cramer-Rao-Inequality, Recursive Estimation, Dynamic System Model Classes (Linear and Nonlinear, Continuous and Discrete Time, State Space and Input Output, White Box and Black Box Models), Application of identification methods to several case studies. The lecture course will also review necessary concepts from the three fields Statistics, Optimization, and Systems Theory, where needed.
Examination achievement
see module details
Course achievement
see module details
Literature
1. Lecture manuscript 2. Ljung, L. (1999). System Identification: Theory for the User. Prentice Hall 3. Lecture manuscript "System Identification" by J
Compulsory requirement
None
Recommended requirement
Undergraduate knowledge in analysis, algebra, differential equations as well as in systems theory and feedback control.

↑

Name of module	**Number of module**
Modelling and System Identification	11LE50MO-2080 PO 2021
Veranstaltung	
Modellbildung und Systemidentifikation / Modelling and System Identification	
Event type	Number
Übung	11LE50Ü-2080
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercises accompany the lecture content and are mostly computer exercises and case studies.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	Number of module
Probability and statistics	11LE50MO-6100 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	1
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
Basic knowledge in mathematics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Probability and statistics	Vorlesung		6.0	2.0	180 hours
Probability and statistics	Übung			2.0	

Qualification
The overall aim of the module is that students will have insights into the field of probability and statistics. Complemented by many examples, the students learn to apply probability theory and statistics in order to analyze data. After the course The students will be able to assess and evaluate the results they obtained.
Examination achievement
Written exam with a duration of 90 minutes
Course achievement
There are exercises at regular intervals that have to be worked on and handed in.These are corrected and assessed with points. The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021) in Advanced Microsystems

↑

Name of module	Number of module
Probability and statistics	11LE50MO-6100 PO 2021
Veranstaltung	
Probability and statistics	
Event type	Number
Vorlesung	11LE50V-6100
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The topics of this course cover:
- Probability theory:
- Discrete random variables
- Continuous random variables
- Statistics:
- Parameter estimation
- Linear and nonlinear regression
- Statistical tests
- Random numbers and Monte-Carlo simulation
- Experimental design
- Statistical process control

Examination achievement

see module details

Course achievement

see module details

Literature

1. M.R. Spiegel, L.J. Stephens, Theory and Problems of Statistics, Schaum's Outline Series, New York
2. J. Honerkamp, Stochastic Dynamical Systems, VCH, Weinheim
3. J. Pitman, Probability, Springer, Corr. 7th printing, 1993
4. D. Stoyan, Stochastik für Ingenieure und Naturwissenschaftler, Akademie Verlag, 1993
5. U. Krengel, Einführung in die Wahrscheinlichkeitstheorie und Statistik: Für Studium, Berufspraxis und Lehramt, Vieweg und Teubner 2005

Compulsory requirement

none

Recommended requirement
Basic knowledge in mathematics
Recommendation
Important information for MSc ESE: According to the exam regulations, this module does **NOT**count towards the 18 compulsory ECTS in Advanced MSE! **Wichtiger Hinweis für MSc ESE:** Diese Modul zählt laut Prüfungsordnung **NICHT** in die 18 Pflicht-ECTS im Berich Advanced MSE!

↑

Name of module	**Number of module**
Probability and statistics	11LE50MO-6100 PO 2021
Veranstaltung	
Probability and statistics	
Event type	Number
Übung	11LE50Ü-6100
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommendation
Important information for MSc ESE: According to the exam regulations, this module does **NOT**count towards the 18 compulsory ECTS in Advanced MSE! **Wichtiger Hinweis für MSc ESE:** Diese Modul zählt laut Prüfungsordnung **NICHT** in die 18 Pflicht-ECTS im Berich Advanced MSE!

↑

Name of module	**Number of module**
Sensors	11LE50MO-7500/986 MSE PO 2021
Responsible	
Prof. Dr. Alexander Rohrbach	
Organizer	
Institut für Mikrosystemtechnik Bio- und Nano-Photonik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	1
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
Basic knowledge in physics, mathematics and materials

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Sensors	Vorlesung		6.0	2.0	180 hours
Sensors Lab Course	Praktikum				

Qualification
Participants should exhibit a comprehensive overview over all technical sensor types, their working principles,measurement ranges, accuracies, their realization technologies.Thermodynamics and material based conversion principles for sensor functions. Students should be enabled to select, apply, optimise, existing sensor types and establish sensor signal handling for a specific task. Furthermore, they should gain abilities to develop novel sensor types and technologies for their realization.
Examination achievement
written examination (usually 90-180 minutes)

Course achievement
To pass the Studienleistung, students need all three reports to get accepted. In case a report is insufficient, students have the option to rework it and resubmit within one week. In total, students have three options to rework. The criteria for approvement of the report are based on the description “Writing a Scientific Lab Report” provided in the lab course manual and the tasks defined for each of the three experiments.
Usability
Compulsory elective mdule for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), in Advanced Microsystems

↑

Name of module	**Number of module**
Sensors	11LE50MO-7500/986 MSE PO 2021
Veranstaltung	
Sensors	
Event type	Number
Vorlesung	11LE50V-7500/986
Organizer	
Institut für Mikrosystemtechnik Sensoren	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The lecture Sensors gives an overview about working principles, physical mechanisms, methods and technologies important for sensors with a focus on microtechnology. A general introduction is followed by specific discussion of various sensor types including for example temperature, radiation, magnetic, mechanical and chemical sensors. The lecture bridges fundamentals and applications of sensors. Sensor examples of university and industrial environment will be shown and opportunities and limitations of these sensors will be discussed.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
Basic knowledge in physics, mathematics and materials

↑

Name of module	**Number of module**
Sensors	11LE50MO-7500/986 MSE PO 2021
Veranstaltung	
Sensors Lab Course	
Event type	Number
Praktikum	11LE50P-7500 PO 2021
Organizer	
Institut für Mikrosystemtechnik Elektr. Messt. u. Eingebettete Sys.	

ECTS-Points	
Hours of week	
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Through the three modules of the lab course, we provide you with hands-on experience to deepen the knowledge from the lectures. We like you to spark your interest in sensor applications playfully, but simultaneously expect a university level performance during the experimentation and while writing your reports. All experiments use the Arduino Nicla Sense ME platform, which comprises four state-of-art integrated sensors, an Arm Cortex M4 processor and Bluetooth connectivity. The different sensors are an inertial measurement unit (IMU) measuring acceleration and rotation, a pressure sensor, a magnetometer, and a gas sensor providing deduced parameters like equivalent CO2 and volatile organic compounds (VOC) concentrations together with temperature and humidity. The lab course consists of self-learning modules for which each student borrows one Nicla Sense ME board. Nothing else is needed besides a computer with a USB port, preferably a notebook. Within the given schedule (i.e., deadlines for report submission), you can work on the experiments at your own pace.
Qualification
You have practical experience with different state-of-art sensors (accelerometer, gyroscope, pressure sensor, magnetometer, gas sensor, humidity sensor, temperature sensor) and an embedded sensor platform. 2. You can program an embedded system to interface with different sensors and provide the data to a connected computer. 3. You know how to perform sensor measurements according to scientific standards. 4. You can analyze sensor data (filtering, integration, differentiation). 5. You can document and appropriately discuss your measurements in a report. 6. You understand the working principles of the different sensors and relate your measurements to the limitations of the sensor principle. Lehrinhalt/
Examination achievement
see module details

Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Microcontroller programming (Arduino C++), Matlab

↑

Name of module	**Number of module**
Biomedical Microsystems	11LE50MO-7900 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	2
Duration	
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Biomedical Microsystems	Vorlesung		6.0	2.0	180 hours
Biomedical Microsystems	Übung			2.0	

Qualification
Objective of the module is to teach the technological requirements of microsystems in biomedical applications. Aspects of material science, standards and directives as well as technological opportunities will be evaluated. Examples from a variety of applications of approved medical devices and research prototypes in clinical trials will be presented and assessed.The module teaches the students which particular requirements have to be taken into account if microsystems should be used as a medical device. It will give a broad overview of the possible extent of microsystems applications in medical devices. The accompanying exercises supplement the lecture with respectto further applications. They guide the students towards independent learning whereas literature research,application and transfer of already acquired technological knowledge strengthen the engineering skills forresearch and development tasks in new application fields.
Examination achievement
Written examination with a duration of 90 minutes
Course achievement
There are exercises at regular intervals which are corrected and assessed with points. The exercises are considered passed if 50% of maximum points will be achieved from the tests that are written in the exercises with prior notice.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), in Advanced Microsystems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Biomedical Microsystems	11LE50MO-7900 PO 2021
Veranstaltung	
Biomedical Microsystems	
Event type	Number
Vorlesung	11LE50V-7900
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The course presents exemplary applications of microsystems in biomedical engineering, discusses challenges and illustrates solutions to meet the requirements of biocompatibility, biostability and reliability in clinical applications. In detail, the following topic will be covered:

- Introduction to Biomedical Microdevices
- Medical Devices: Legal Framework and Classification
- Glaucoma Monitoring Implant
- Neual Implants to Restore Vision
- Neural Implants to Record from the Brain
- Sensors in Cardiac Pacemakers
- Imaging Pills
- Spectroscopic Billirubin Measurement
- Trends for Intelligent Endoprostheses
- Stability and Functionality Implantable MEMS
- Packaging and Housing Concepts
- Data and Energy Transmission in (Micro-)Implants

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.

Examination achievement

see module details

Course achievement

see module details

Literature

Actual copies of the slides will be delivered accompanying to the lectures.

Literature: ■ G. A. Urban (ed.) BioMEMS. Dordrecht: Springer 2006.
Compulsory requirement
none

↑

Name of module	**Number of module**
Biomedical Microsystems	11LE50MO-7900 PO 2021
Veranstaltung	
Biomedical Microsystems	
Event type	Number
Übung	11LE50Ü-7900
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Micro-actuators	11LE50MO-7300 PO 2021
Responsible	
Prof. Dr.-Ing. Ulrike Wallrabe	
Organizer	
Institut für Mikrosystemtechnik Mikroaktorik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none
Recommended requirement
Basic knowledge in Physics, Electrical Engineering, Engineering Mechanics and Microsystems Technologies and Processes

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Micro-actuators - Vorlesung	Vorlesung		6.0	2.0	180 hours
Micro-actuators	Übung			2.0	

Qualification
The students should get acquainted with the most common actuation principles. This includes the basic knowledge of the physical principles and equations, the integration into micro technology and the specific fabrication processes and applications. Furthermore the critical examination of the different actuation principles is also encouraged. After the course, the students should be familiar with the advantages and disadvantages of the different actuation principles and be able to choose the right mechanism for a novel application with respect to the typical parameters like force and displacement, but also complexity of the fabrication process, ease of integration and reliability.
Examination achievement
written examination with a duration of 120 minutes If the number of participants is small (< 20), an oral examination of 45 minutes may be held instead. The students will be informed in good time.

Course achievement
Each student has to present one exercise solution on the black board. This is not marked, but counted as "Studienleistung".
Recommendation
It is strongly recommended to pass the Studienleistung before taking the exam.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), in Advanced Microsystems ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

↑

Name of module	**Number of module**
Micro-actuators	11LE50MO-7300 PO 2021
Veranstaltung	
Micro-actuators - Vorlesung	
Event type	Number
Vorlesung	11LE50V-7300
Organizer	
Institut für Mikrosystemtechnik Mikroaktorik	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The lecture starts off with a short recapitulation of the principles of mechanical engineering that are especially relevant for actuators: Newtonian mechanics, force, impulse, energy, torque, friction, forced oscillation with and without damping, resonance, waves and the wave equation.
Then the actuation principles mentioned below are worked through. For each principle the specific basic physical equations are presented. Afterwards the integration of that principle into micro technology and typical examples of scientific literature or commercial products are shown. The actuation principles are:

Electrostatics
First the plate capacitor with one direction of motion perpendicular to the plate is introduced. The special pull-in characteristic is derived.
Then the direction of motion parallel to the plate is covered, which resembles a comb actuator leading to a linear or tilting motion, depending on the design of the actuator.
Lastly rotating motors are covered.

Electromagnetics
The easiest actuator uses the Lorentz force. Here the possibility of using bi-stable and snap-action mechanisms arises.
After the Lorentz-force actuators, magnetic reluctance actuators with the challenge of coil winding, the use of eddy currents and the assembly of small electromagnetic motors are discussed.

Piezoelectricity
Piezoelectric behavior is first introduced using the example of SiO_2, followed by PZT. Since piezo actuators are commonly obtained as modular parts, typical commercially available designs are presented and standard applications are discussed.
As a special case, surface waves excited within a piezoelectric substrate are shown. The applications of these devices include RFID-tags and friction-controlled rotary motors.

Shape Memory Metals

The special behavior of NiTi is introduced concerning the aspect of shape memory and super elasticity. The method of shape settings is illustrated, followed by numerous examples, especially super elasticity used in medical engineering.

Polymer actuators
Less known for hydroactive polymers, polymer actuators are a common synonym for dielectric elastomer actuators. The importance of the choice of the actuator material and the influence of the material on percolation and the dielectric constant is exemplified. Typical challenges and applications for polymer actuators are identified.

Hydrodynamic
After a theoretical introduction to fluid dynamics, two types of turbines are presented: Firstly actual micro turbines, where the challenge of friction can be exemplified and secondly turbines in the millimeter range for surgical applications.
This is followed by active multi-pathway valves and a short overview over micro pumps.

Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
Basic knowledge in Physics, Electrical Engineering, Engineering Mechanics and Microsystems Technologies and Processes

↑

Name of module	**Number of module**
Micro-actuators	11LE50MO-7300 PO 2021
Veranstaltung	
Micro-actuators	
Event type	Number
Übung	11LE50Ü-7300
Organizer	
Institut für Mikrosystemtechnik Mikroaktorik	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Micro-fluidics	11LE50MO-7152 PO 2021
Responsible	
Prof. Dr.-Ing. Roland Zengerle	
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine
Recommended requirement
Basic knowledge in physics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Microfluidics	Vorlesung		6.0	2.0	180 hours
Microfluidics	Übung			2.0	

Qualification
Technically correct handling of very small amounts of liquid and gas is of central importance in all key areas of microsystems engineering such as Lab-on-a-Chip applications, InkJet technology, fuel cells, medical drug delivery systems and many more. This lecture gives an overview on physical phenomena and presents some of the most important application examples of microfluidic systems. The educational objective of the Microfluidics I lecture is to gain a general understanding regarding all basic microfluidic effects including fluid mechanics, fluid properties and both physical as well as chemical interactions at boundary layers. Participating students will learn to apply micro- and macrofluidic effects and phenomena to design new systems. This is achieved by introducing basic microfluidic elements that can be utilized as elementary units to create complex microfluidic devices.

Examination achievement
Written exam with a duration of max. 180 minutes It is highly recommended to take the examination in the same term when attending the lecture and the tutorials.
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), in Advanced Microsystems

↑

Name of module	**Number of module**
Micro-fluidics	11LE50MO-7152 PO 2021
Veranstaltung	
Microfluidics	
Event type	Number
Vorlesung	11LE50V-7152
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	

ECTS-Points	6.0
Workload	180 hours
Attendance	52
Independent study	128
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The topics of this course are:

- Basic fluid properties
- Fluid dynamics including the Navier-Stokes-Equation
- Diffusion
- Surface tension
- Electrokinetics
- The design of microfluidic chips
- Basic fluidic elements

Examination achievement

see module details

Course achievement

none

Literature

Literatur:

- Nguyen, Wereley; Microfluidics, Artech House
- Geschke, Klank, Telleman; Microsystem Eng. of Lab-on-a-Chip Devices, Wiley-VCh, 2nd edition
- Bruus; Theoretical Microfluidics, Oxford Univ. Press

Compulsory requirement

none

Recommended requirement

Basic knowledge in physics

↑

Name of module	**Number of module**
Micro-fluidics	11LE50MO-7152 PO 2021
Veranstaltung	
Microfluidics	
Event type	Number
Übung	11LE50Ü-7152
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
none
Compulsory requirement
none
Recommended requirement
none

↑

Name of node	**Number of node**
Concentration Areas	11LE50KO-WP-MSc-986-2021 WP2
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

Comment
There are four different concentration areas: Circuits and Systems, Materials and Fabrication, Biomedical Engineering und Photonics. Students will choose one of these four areas and complete 30 ECTS points in the same area. Up to 9 of these 30 ECTS points may be completed in the Customized Course Selection area.

↑

Name of node	**Number of node**
Circuits and Systems	11LE50KO-WP-MSc-986-2021 WP2 CuS
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

↑

Name of module	**Number of module**
Angewandte Sensorschaltungstechnik	11LE50MO-5268 PO 2021
Responsible	
Prof. Dr. Peter Woias	
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	in jedem Semester

Compulsory requirement
Keine
Recommended requirement
Keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Angewandte Sensorschaltungstechnik - Praktische Übung	Praktikum		3.0	2.5	180 Stunden

Qualification
Die Studierenden haben praktisches "hands-on" Wissen zum Design, zur Simulation, zur Herstellung und zum Test einer elektronischen Sensorschaltung erworben. Sie sind in der Lage elektronische Schaltungen zu entwickeln, diese in PSPICE zu simulieren, ein Schaltungslayout zu entwerfen und die Schaltung als Platine aufzubauen. Sie können eine Schaltung messtechnisch charakterisieren und können ihre Ergebnisse in Form einer Kurzpräsentation vorstellen.
Examination achievement
Praktische Prüfungsleistung (Erstellung von Demonstratoren oder Software).
Course achievement
Durchführung und Teilnahme an Versuchen im zweiwöchentlichen Rhythmus.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Microsystems Engineering, (PO 2021) Concentration Circuits and Systems ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Circuits and Systems

↑

Name of module	Number of module
Angewandte Sensorschaltungstechnik	11LE50MO-5268 PO 2021
Veranstaltung	
Angewandte Sensorschaltungstechnik - Praktische Übung	
Event type	Number
Praktikum	11LE50prÜ-5268
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	

ECTS-Points	3.0
Workload	180 Stunden
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.5
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Inhalte sind: • Entwurf des Schaltungskonzeptes für ein elektronisches Sensorinterface • PSPICE-Simulation des gefundenen Konzeptes, Optimierung der Schaltung • Platinenlayout • Platinenfertigung und -bestückung • Schaltungstest • Abschlußpräsentation
Examination achievement
siehe Modulebene
Course achievement
siehe Modulebene
Literature
Tietze, Schenk, Gamm, Halbleiter-Schaltungstechnik, 15. Auflage, 2016, Springer, Berlin, ISBN 978-3-662-48354-1. Schrüfer, Reindl, Zagar, Elektrische Messtechnik, 11. Auflage, 2014, Carl-Vieweg-Verlag, München, ISBN 978-3-446-44208-5.
Compulsory requirement

↑

Name of module	**Number of module**
CMOS-Integrierte Mikrosysteme / CMOS MEMS	11LE50MO-5271 PO 2021
Responsible	
Prof. Dr. Oliver Paul	
Organizer	
Institut für Mikrosystemtechnik Materialien der Mikrosystemtechnik	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
Knowledge of sensors, MEMS technologies, semiconductor physics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
CMOS-Integrierte Mikrosysteme / CMOS MEMS	Vorlesung		6.0	2.0	180 hours
CMOS-Integrierte Mikrosysteme / CMOS MEMS	Übung			2.0	

Qualification
The commercially most successful microsystems to date have been based on silicon. Companies such as Bosch, Analog Devices, Texas Instruments, Sensirion, and other small and medium enterprises have built their success on this wise technological choice which allows to co-integrate microsystems compatible with silicon foundry services and commercial silicon technologies, in particular CMOS technologies. It will offer a healthy mix of technology, physical sensor principles and operating techniques, and will be enriched with examples that made it into the market and others that have remained scientific visions. In tune with the progress of the lecture material, home-work will be assigned, with the presentation and discussion of solutions by students during the course hours. In summary, the attendees will acquire a broad range of skills towards becoming productive engineers in the field of smart MEMS.
Examination achievement
Oral examination if there are 20 or fewer than 20 registered participants; written examination if there are more than 20 registered participants (minimum 60 and maximum 240 minutes). Details will be announced by the examiner in due time.

Course achievement
The "Studienleistung" consists of (1) the documented, successful attempt to solve more than 60% of the homework problems (as checked weekly); "60% of the homework problems" means the fraction of the overall number of homework problems proposed during the course, not of each homework problem separately; "successful" means that the solution could be presented by the student in front of the class; (2) the presentation of a representative number of solutions of homework problems in front of the class.
Usability
Compulsory elective module for students of the study program ■ M.Sc.Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltunen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Circuits and Systems

↑

Name of module	**Number of module**
CMOS-Integrierte Mikrosysteme / CMOS MEMS	11LE50MO-5271 PO 2021
Veranstaltung	
CMOS-Integrierte Mikrosysteme / CMOS MEMS	
Event type	Number
Vorlesung	11LE50V-5271
Organizer	
Institut für Mikrosystemtechnik Materialien der Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Attendance	60 hours
Independent study	120 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
1. Introduction 2. Basic technologies 3. Magnetic sensors 4. Stress sensors 5. Inertial sensors 6. Thermal sensors 7. Radiation sensors 8. Calibration
Examination achievement
see module details
Course achievement
see module details
Literature
A script will be handed out during the course.
Compulsory requirement
none
Recommended requirement
Knowledge of sensors, MEMS technologies, semiconductor physics

↑

Name of module	**Number of module**
CMOS-Integrierte Mikrosysteme / CMOS MEMS	11LE50MO-5271 PO 2021
Veranstaltung	
CMOS-Integrierte Mikrosysteme / CMOS MEMS	
Event type	Number
Übung	11LE50Ü-5271
Organizer	
Institut für Mikrosystemtechnik Materialien der Mikrosystemtechnik	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercises will deepen the topics treated during the lecture. They will allow the students to rethink and rework the more theoretical aspects and apply them to realistic examples inspired from commercial products and more academic ideas. Thereby they will see their vision sharpened for the challenges awaiting them in their future professional work in the area of smart MEMS. Solution approaches to the homework problems will be presented weekly by the participants and discussed and elaborated upon with the group of colleagues under the guidance of the professor. This discursive, participative approach allows to learn more than by being presented with up-front oral or written solutions.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Data Converters	11LE50MO-5227 PO 2021
Responsible	
Dr.-Ing. Matthias Keller	
Organizer	
Institut für Mikrosystemtechnik Mikroelektronik	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Attendance	28 Stunden
Independent study	62 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
Successful completion of the module 5070 - *Micro-electronics*. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade.
Recommended requirement
A good understanding of the knowledge imparted in the Micro-electronics module (5070) is crucial for a successful completion of this module.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Data Converters	Vorlesung		3.0	2.0	90 Stunden

Qualification
Upon completion of the course, students will ■ have a thorough understanding of the fundamentals and mathematical depiction of A/D and D/A conversion ■ be in the position to select, for a given application, the right A/D or D/A converter among the state-of-the-art architectures ■ know about performance limiting non-idealities of A/D and D/A converters and how to minimize or compensate their effect.
Examination achievement
Written exam at the end of the term with a duration of 2h on the content of the lecture.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	**Number of module**
Data Converters	11LE50MO-5227 PO 2021
Veranstaltung	
Data Converters	
Event type	Number
Vorlesung	11LE50V-5227 PO 2021
Organizer	
Institut für Mikrosystemtechnik Mikroelektronik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	28 Stunden
Independent study	62 Stinden
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The focus of the course is put on two of the most demanding building blocks for mixed-signal circuit design: the analog-to-digital (A/D) and the digital-to-analog (D/A) converter. With steadily advancing digitization, these components have to satisfy the demands for ever increasing bandwidth, resolution, and optimum power efficiency.

The course covers

- the fundamentals of data conversion, i.e., filtering, sampling, and quantization for A/D conversion and digital-to-analog conversion, analog hold, and reconstruction for D/A conversion
- the static and spectral metrics and nonidealities of A/D and D/A converters, e.g., gain/offset error, integral/differential nonlinearity, dynamic range, signal-to-noise(-and-distortion) ratio, etc.
- an overview and discussion of state-of-the-art Nyquist D/A converters
- an overview and discussion of state-of-the-art Nyquist and oversampled A/D converters.

Examination achievement

see Module details

Course achievement

see Module details

Compulsory requirement

Successful completion of the module 5070 - *Micro-electronics*. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade.

Recommended requirement
A good understanding of the knowledge imparted in the Micro-electronics module (5070) is crucial for a successful completion of this module.
Recommendation
■ **In case of comments and/or questions, please contact Dr.-Ing. M. Keller (mkeller@imtek.de).** ■ Application for participation is to be performed as soon as possible in HISinOne, even if the result of the exam *Mikroelektronik* / *Microelectronics* is not yet available. Students will get informed on their status, i.e., "accepted / waiting list / rejected", once the results of the exam are available. ■ No participation in the first lecture results in the cancellation of an accepted application. The seat will be given to the first student on the waiting list.

↑

Name of module	**Number of module**
Debugging and Fuzzing	11LE13MO-1158_PO 2020
Responsible	
Prof. Dr. Armin Biere	
Organizer	
Institut für Informatik Rechnerarchitektur	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden | hours
Recommended semester	1
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine | none
Recommended requirement
Good programming experience necessary Highly recommended: Advanced Programming Skills (in C, C++, Java, or Python) Basic knowledge in Software Engineering, Algorithms and Data-Structures

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Debugging and Fuzzing	Vorlesung		6.0	2.0	180 Stunden | hours
Debugging and Fuzzing	Übung			2.0	

Qualification
The main goal is to understand debugging from a scientific perspective and learn how to apply advanced debugging techniques to real world system design mostly in the context of software engineering and in combination with modern fuzzing and testing techniques.
Examination achievement
Written exam (usually 90 to 180 minutes)
Course achievement
You have to complete and hand in your solutions for exercise sheets and perform experiments on a regular basis. These will be scored and awarded with points. To successfully complete the course work (Studienleistung), you need to have reached at least 50% of the overall number of achievable points for the semester.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	Number of module
Debugging and Fuzzing	11LE13MO-1158_PO 2020
Veranstaltung	
Debugging and Fuzzing	
Event type	Number
Vorlesung	11LE13V-1158_PO 2020
Organizer	
Institut für Informatik Rechnerarchitektur	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
We will discuss failures, tracking, contracts/assertions,delta-debugging, quick-check, symbolic debugging, coverage, automatic/unit/regression/combinatorial/model-based testing, data-races, deadlocks, sanitizers and also spend some time on fuzzing, including white/gray/black-box fuzzing, coverage, grammar-aware fuzzing, and symbolic execution.
Examination achievement
See module level
Course achievement
See module level
Literature
"Why Programs Fail", A. Zeller. "The Fuzzing Book", A. Zeller et.al.
Compulsory requirement
Recommended requirement
Good programming experience necessary Highly recommende: Advanced Programming Skills (in C, C++, Java, or Python) Software Engineering, Algorithms and Data-Structures

↑

Name of module	**Number of module**
Debugging and Fuzzing	11LE13MO-1158_PO 2020
Veranstaltung	
Debugging and Fuzzing	
Event type	Number
Übung	11LE13Ü-1158_PO 2020
Organizer	
Institut für Informatik Rechnerarchitektur	

ECTS-Points	
Attendance	30
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Using the acquired debugging techniques in exercises on paper and applying debugging and fuzzing tools to real complex code from automated reasoning, electronic design automation or compilers.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Embedded Computing Entrepreneurship (2ES)	Vorlesung		6.0	1.0	180 Stunden / Hours
Embedded Computing Entrepreneurship (2ES)	Seminar			1.0	
Embedded Computing Entrepreneurship (2ES)	Übung			2.0	

Qualification
* Conceptualise and design embedded sensor systems along a specific application. * Develop and demonstrate key components of embedded sensor systems, including signal and pattern analysis and recognition algorithms. * Develop a basic market analysis and business plan. * Implement an agile development process.
Examination achievement
Presentation followed by an oral examination (10 minutes per person, total duration depends on group size)

Course achievement
Regular attendance of the course (seminar and exercise) according to §13 (2) of the General Examination Regulations for the Bachelor of Science/Master of Science, as otherwise the required group work and scientific discussion is not possible. Further elements of the course work are the creation of demonstrators or software as well as a written elaboration/protocol.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems **OR** Elective Courses in Computer Science ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung **|** Specialization Courses Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	Number of module
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Veranstaltung	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
Vorlesung	11LE13V-1404_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	16 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
The course combines technical and business-related lectures on embedded sensor systems with a practical system development project using agile development methods. Students will organise in groups and define together with their advisor(s) goals for the technical development, market analysis, etc. Student groups can enter their projects for an award of the VDE.
Examination achievement
see module details
Course achievement
see module details
Literature
Relevant literature will be provided during the lectures and consultations.
Compulsory requirement
None
Recommended requirement
Basic pattern recognition methods; basic programming skills

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Veranstaltung	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
Seminar	11LE13S-1404_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	
Attendance	16 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Veranstaltung	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
Übung	11LE13Ü-1404_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Name of Non-graded work	
Exam type	Number
Responsible	
Faculty	

Exam form	
Grading	
Compulsory	

↑

Name of module	Number of module
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Name of Examination	
Exam type	Number
Responsible	
Faculty	

Exam form	
Grading	
Recommended semester	2
Compulsory	

↑

Name of module	**Number of module**
Energiegewinnung / Energy harvesting	11LE50MO-5703 PO 2021
Responsible	
Prof. Dr. Peter Woias	
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Energiegewinnung / Energy harvesting	Vorlesung		6.0	2.0	180 hours
Energiegewinnung / Energy harvesting	Übung			2.0	

Qualification
The students know the basic principles of (micro) energy harvesting. They know several energy conversion techniques, energy storage concepts and power management strategies in detail. The students are able to estimate the energy generation of different harvesting techniques and to work on the design of energy autonomous embedded systems. The importance of the system-level design in these systems is, in general, a central objective in this class.
Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes) Wenn die Teilnehmerzahl gering ist (< 20), kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert.| If the number of participants is small (< 20), an oral examination may be held instead. The students will be informed in good time.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Crcuits and Systems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in MIcrosystems Engineering Concentration Area Circuits and Systems

↑

Name of module	**Number of module**
Energiegewinnung / Energy harvesting	11LE50MO-5703 PO 2021
Veranstaltung	
Energiegewinnung / Energy harvesting	
Event type	Number
Vorlesung	11LE50V-5703
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 hours
Independent study	128 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Harmonical Oscillator (with bending beams)
- Piezoelectric Energy Harvesters
- Electrodynamic Energy Harvesters
- Electrostatic Energy Harvesters
- Non-Resonant Generators
- Thermoelectric Generators & Processes
- Thermomechanic Generators
- Capacitive Storages and Accumulators
- Step-up Converters and Advanced Step-up Converter Design
- Energy Harvesting Applications

Examination achievement

See module details

Course achievement

See module details

Literature

- S. Roundy et al, "Energy Scavenging for Wireless Sensor Networks: with Special Focus on Vibrations", 2004, Kluver Academic Publishers Group, The Netherlands
- D. Priya, S. Shank, "Energy Harvesting Technologies", 2009, Springer Science+Business Media LLC, New York

Compulsory requirement

None

Recommended requirement

None

↑

Name of module	**Number of module**
Energiegewinnung / Energy harvesting	11LE50MO-5703 PO 2021
Veranstaltung	
Energiegewinnung / Energy harvesting	
Event type	Number
Übung	11LE50Ü-5703
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
See module details
Course achievement
See module details
Compulsory requirement

↑

Name of module	Number of module
Energy Efficient Power Electronics	11LE50MO-9010 PO 2021
Responsible	
Prof. Dr. Oliver Ambacher Prof. Dr. Bruno Burger Prof. Dr. Rüdiger Quay	
Faculty	
Technische Fakultät Institut für Nachhaltige Technische Systeme	

ECTS-Points	6.0
Workload	180 h
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
Basic knowledge of electric and electronic circuits.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Energy Efficient Power Electronics - Vorlesung	Vorlesung		6.0	2.0	
Energy Efficient Power Electronics	Übung			2.0	

Qualification
Students will be enabled to understand materials, functioning and design of up to date power devices and circuits suitable for energy efficient power electronic systems. The lecture comprises three aspects: fundamental material and device concepts, power conversion-circuitry and power conversion systems. This includes high voltage AC-DC converter, solar energy photovoltaic converters and converters for engines or windcraft systems. The basic concepts of power conversion, of passive and active semiconductor devices, high-voltage operation, converter- and control concepts, device protection and aspects of system and power network theory are provided. The students will be competent to analyze, understand the fabrication, design of passive and active power devices such as MOSFETs, Insulated Gate Bipolar IGBTs, Junction FETs (JFET), diodes, and thyristors. Students will be able to design and analyze feedback control systems based on state space control technologies and apply them to power devices.
Examination achievement
Written supervised exam, duration: 120 min. The final written exam covers the content of the lecture (70%) and exercise (30%). Important info for exchange students: the exam must be taken at the official examination date.

Course achievement
None
Usability
Mandatory elective module for students of the study program ■ M.Sc. in Sustainable Systems Engineering (PO 2021) in the technical concentration area *Energy Systems Engineering* Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Crcuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	**Number of module**
Energy Efficient Power Electronics	11LE50MO-9010 PO 2021
Veranstaltung	
Energy Efficient Power Electronics - Vorlesung	
Event type	Number
Vorlesung	11LE68V-9010 PO 2021

ECTS-Points	6.0
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The lecture deals with the materials, topologies and concepts of power devices and circuits. It comprises three parts: fundamental material and device concepts, power conversion-concepts and actual power conversion systems. At the interface of modern electronics, circuit design, and control theory, advanced analysis, fabrication, and characterization techniques are introduced in order to bridge the gap from modern power conversion to the understanding of systems and network systems with all aspects of power conversion. The methodologies of power-analysis, design of circuits, complex power flow, processing of devices, their modelling, their characterization, and control are introduced along with the demonstration of their relevance to real power-components and -systems. Circuits and system concepts for power conversion, such as half and full bridges, current controls, aspects high voltage operation, and design for robustness are presented, and several examples are discussed in detail. Typical applications include DC-DC conversion for server systems, photovoltaic power conversion, application to microscopic power converters, and high-voltage windcraft systems.

Examination achievement

See module

Course achievement

See module

Literature

- Joachim Specovices: „Grundkurs Leistungselektronik“ Vieweg + Teubner (2009) ISBN 9783834805577
- Manfred Michel: „Leistungselektronik“ Springer (2011) ISBN 9783642159831
- C. Kamalakannan et al.: „Power Electronics and Renewable Energy Systems“ Springer (2014) ISBN 8132221184

Compulsory requirement

None

Recommended requirement

Basic knowledge of electric and electronic circuits.

Teaching method

Lecture + exercise

↑

Name of module	**Number of module**
Energy Efficient Power Electronics	11LE50MO-9010 PO 2021
Veranstaltung	
Energy Efficient Power Electronics	
Event type	Number
Übung	11LE68Ü-9010 PO 2021

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
In the exercises, the contents of the lecture will be illustrated and deepened by means of examples. The students learn in their home studies on the basis of exercise sheets, e.g. to calculate the electrical properties of power electronic devices and circuits, as well as to estimate the lifetime, ruggedness, and energy efficiency of power electronic systems. During the exercises the solutions of the tasks and problems are presented by tutors and explained in detail.
Examination achievement
See module
Course achievement
See module
Compulsory requirement

↑

Name of module	**Number of module**
Entwurf Analoger CMOS Schaltungen / Analog CMOS Circuit Design	11LE50MO-5202 PO 2021
Responsible	
Prof. Dr.-Ing. Matthias Kuhl	
Organizer	
Institut für Mikrosystemtechnik Mikroelektronik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 Stunden
Independent study	128 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none
Recommended requirement
• system theory (basics) • electronic devices and circuits (MOS transistor)

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Entwurf Analoger CMOS Schaltungen / Analog CMOS Circuit Design	Vorlesung		6.0	2.0	180 hours
Entwurf Analoger CMOS Schaltungen - Praktikum / Analog CMOS Circuit Design - Laboratory	Praktikum			2.0	

Qualification
• After completing the module, students are familiar with complex analog CMOS circuit design concepts and are thus in the position to analyze and design arbitrary analog circuits. • The students master the state-of-the-art design approach gm/Id and are thus able to design and implement analog circuits in an arbitrary technology node. • The students improve their skills in the frequency analysis of feedback systems and are thus able to define the phase margin of feedback systems by relocating poles and zeros. • The students know how to analyze the noise performance of analog integrated circuits and how to meet noise specifications.

Examination achievement
Written exam at the end of the term with a duration of 2h on the content of the module. The lecture and the project represent a module; the mark of the written exam will thus be weighted by 6 ECTS.
Course achievement
■ five graded reports, presentation (at the end of the term) ■ The practical exercise *Analog CMOS Circuit Design - Laboratory* is successfully passed if the final presentation is passed and an average grade of 70% is achieved in the five written reports. ■ The lecture and the project represent a module; the mark of the written exam will thus be weighted by 6 ECTS.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Crcuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in MIcrosystems Engineering Concentration Area Circuits and Systems

↑

Name of module	Number of module
Entwurf Analoger CMOS Schaltungen / Analog CMOS Circuit Design	11LE50MO-5202 PO 2021
Veranstaltung	
Entwurf Analoger CMOS Schaltungen / Analog CMOS Circuit Design	
Event type	Number
Vorlesung	11LE50V-5202
Organizer	
Institut für Mikrosystemtechnik Mikroelektronik	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 hours
Independent study	128 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The fundamentals of microelectronics were presented in the course Microelectronics, in particular the square-law / lambda model depicting the current-voltage characteristic of MOS transistors in different working regions. The square-law model allows gaining a quick and intuitive understanding of the large- and small-signal behavior of the MOS transistor. However, for performing integrated analog circuit design, a more accurate model is required that provides excellent matching between hand calculations and simulations, in particular for modern nanometer CMOS technologies. At first, the gm/Id design methodology will thus be presented. It will be illustrated by and applied to the design and transistor-level implementation of a typical analog circuit, i.e., a two-stage amplifier, in the practical exercise.

Another focus of the course is put on the fundamentals of electrical noise, i.e., understanding, predicting, and minimizing noise in CMOS circuits. In addition to the minimization of thermal and 1/f-noise by proper sizing of transistors, the sampled or chopped operation of analog amplifiers will be introduced as a measure to efficiently suppress the CMOS transistor's inherent 1/f-noise. Moreover, it will be shown that chopping also allows for the compensation of further non-idealities such as offset or saturation.

The course concludes with the introduction of circuit blocks that are needed for the implementation of near-complete systems, i.e., electrical references for voltage, current, temperature, and time. Moreover, advanced differential architectures will be presented, e.g., folded cascode and inverter-based amplifiers or Gm-C filters. One of these circuit blocks will be analyzed in class by the participants themselves in a simplified flipped-classroom scenario.

Examination achievement

see module details

Course achievement

see module details

Literature

- Script

- P. E. Allen and D. R. Holberg, CMOS Analog Circuit Design, Oxford Press, 2002
- B. Razavi, Design of Analog CMOS Integrated Circuits, McGraw-Hill, 2001

Compulsory requirement
Successful completion of the module 5070 - Micro-electronics. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade.

Recommended requirement
■ Successful completion of the module 5070 - Micro-electronics. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade. ■ system theory (basics)

Recommendation
■ **In case of comments and/or questions, please contact M. Sc. C. Grandauer (christoph.grandauer@imtek.de).** ■ Application for participation is to be performed as soon as possible in HISinOne, even if the result of the exam *Mikroelektronik* / *Microelectronics* is not yet available. Students will get informed on their status, i.e., "accepted / waiting list / rejected", once the results of the exam are available. ■ No participation in the first lecture results in the cancellation of an accepted application. The seat will be given to the first student on the waiting list.

↑

Name of module	Number of module
Entwurf Analoger CMOS Schaltungen / Analog CMOS Circuit Design	11LE50MO-5202 PO 2021
Veranstaltung	
Entwurf Analoger CMOS Schaltungen - Praktikum / Analog CMOS Circuit Design - Laboratory	
Event type	Number
Praktikum	11LE50Ü-5202
Organizer	
Institut für Mikrosystemtechnik Mikroelektronik	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Based on the example of a two-stage amplifier with RC compensation, the practical exercise illustrates the typical design flow of analog integrated circuits. It goes hand in hand with the lecture and trains the students on the implementation of analog integrated circuits based on the gm/Id design approach. After an inital analysis of the circuit by means of hand calculations, the circuit will be implemented and simulated on transistor level using the software Cadence Spectre in order to verify its functionality. In the end, the design will be iteratively improved to withstand real-life conditions and nonidealities, e.g., temperature-, process-, and parameter variations. The student will thus learn that an understanding of the circuit's parameters and their interactions is essential for a successful implementation of an integrated circuit. At the end of the term, a presentation is to be given that covers the design on transistor level.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
■ Successful completion of the module 5070 - Micro-electronics. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade.
Recommended requirement
■ Successful completion of the module 5070 - Micro-electronics. The limited number of 20 seats will be distributed among applying students based on the ranking of the module grade. ■ system theory (basics)
Recommendation
■ Application for participation is to be performed as soon as possible in HISinOne, even if the result of the exam Mikroelektronik / Microelectronics is not yet available. Students will get informed on their status, i.e., "accepted / waiting list / rejected", once the results of the exam are available. ■ No participation in the first lecture results in the cancellation of an accepted application. The seat will be given to the first student on the waiting list.

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Name of module	**Number of module**
Entwurf von CMOS Mixed-Signal Schaltungen / Mixed-Signal CMOS Circuit Design	11LE50MO-5208 PO 2021
Responsible	
Dr.-Ing. Matthias Keller	
Organizer	
Institut für Mikrosystemtechnik Mikroelektronik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
This course is a continuation of module 5202 Analog CMOS Circuit Design, since the layout for the microelectronic circuit designed at transistor level in module 5202 is to be designed in module 5208. Therefore, successful completion of the module Analog CMOS Circuit Design (offered in the summer term) is mandatory for participation in this module.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Entwurf von CMOS Mixed-Signal Schaltungen / Mixed-Signal CMOS Circuit Design - Praktikum	Praktikum		3.0	2.0	90 hours

Qualification
This practical exercise deals with the layout of the two-stage amplifier with RC compensation which was designed on transistor level in the practical exercise Analog CMOS Circuit Design. It thus represents the second major task in the chain of the design flow of an integrated circuit consisting of “Design on transistor level”, “Layout” and “Fabrication and Verification”. Students are able to apply basic layout techniques for transistors, resistors, capacitors, and metal layers using industry standard layout und simulation software. They can employ techniques for the reduction of mismatch such as unit elements, multi-finger transistors, interdigitation, common centroid, or guard rings. At the end of the course, the students are able to compare the results of simulations on transistor and layout level so that they can extract the influence of parasitic resistors and capacitors on the overall performance of the amplifier. At the same time, they learn to optimize the layout with respect to these non-idealities.
Examination achievement
▪ 5x graded reports (10% of the final grade each) ▪ 1x graded presentation (50% of the final grade)

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Crcuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	**Number of module**
Entwurf von CMOS Mixed-Signal Schaltungen / Mixed-Signal CMOS Circuit Design	11LE50MO-5208 PO 2021
Veranstaltung	
Entwurf von CMOS Mixed-Signal Schaltungen / Mixed-Signal CMOS Circuit Design - Praktikum	
Event type	Number
Praktikum	11LE50P-5208
Organizer	
Institut für Mikrosystemtechnik Mikroelektronik	

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Layout of analog CMOS integrated circuits (basics)
- Introduction of the layout tool Cadence VirtuosoXL (industry standard)

Examination achievement

see module details

Course achievement

none

Literature

- Script
- R. J. Baker, CMOS Circuit Design, Layout, and Simulation, IEEE Press Series, 2008
- A. Hastings, The Art of Analog Layout, Pearson Education 2005

Compulsory requirement

This course is a continuation of module 5202 Analog CMOS Circuit Design, since the layout for the micro-electronic circuit designed at transistor level in module 5202 is to be designed in module 5208. Therefore, successful completion of the module Analog CMOS Circuit Design (offered in the summer term) is mandatory for participation in this module.

Recommendation

In case of comments and/or questions regarding the practical exercise "Mixed Signal CMOS Circuit Design", please contact Dr.-Ing. M. Keller (mkeller@tf.uni-freiburg.de).

↑

Name of module	**Number of module**
Flugregelung Praktikum / Flight Control Laboratory	11LE50MO-5222 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
None
Recommended requirement
The lab course includes topics as part of the HIGHWIND project (Simulation, Optimimization and Control of High-Altitude Wind Power Generators). As the HIGHWIND project offers a large variety of project topics, students may be assigned topics meeting best their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Flugregelung Praktikum / Flight Control Laboratory	Praktikum		6.0	4.0	180 hours

Qualification
The students will be able to use a theoretical background for real applications in a scientific project. They will be able to find creative solutions to problems and to perform hands-on testing/verification of soft- and hardware. Furthermore, they will have gained experience of working in an international team.
Examination achievement
Project work: ■ A working project result ■ project documentation and oral presentation
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	Number of module
Flugregelung Praktikum / Flight Control Laboratory	11LE50MO-5222 PO 2021
Veranstaltung	
Flugregelung Praktikum / Flight Control Laboratory	
Event type	Number
Praktikum	11LE50P-5222
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	6.0
Workload	180 hours
Attendance	84 hours
Independent study	96 hours
Hours of week	4.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents

In order to register to this course please write a mail to us (moritz.diehl@imtek.uni-freiburg.de, tommaso.sartor@imtek.uni-freiburg.de) including:

- Short motivation statements,
- A brief summary of your relevant achievements in the field of engineering, exams, university projects, personal projects.
- If you already have an idea for a project on which you are interested to work on feel free to add that.

Focus of the lab course is making a real flight control system work for small aerial vehicles equipped with a variety of sensing and actuation equipment. These vehicles, airplanes, quadrotors or helicopters, might be remote controlled or autonomous. They might flight freely or be connected to the ground via a tether. The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.

Examination achievement

see module details

Course achievement

None

Compulsory requirement

None

Recommended requirement

The lab course includes topics as part of the HIGHWIND project (Simulation, Optimimization and Control of High-Altitude Wind Power Generators). As the HIGHWIND project offers a large variety of project topics,

students may be assigned topics meeting best their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

↑

Name of module	**Number of module**
Leistungselektronik für die Elektromobilität/Power Electronics for E-Mobility	11LE50MO-4106 PO 2021
Responsible	
Prof. Dr. Anke Weidlich	
Organizer	
Institut für Nachhaltige Technische Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	28 Stunden
Independent study	62 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
Power Electronic Circuits and Devices (elective module)

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Leistungselektronik für die Elektromobilität - Vorlesung	Vorlesung		3.0	2.0	Attendance: 24 h lecture + 6 h exercise = 30 hSelf-study: 60 h90 h

Qualification
It is the aim of this module to get a fundamental understanding of power electronic circuits used in E-Mobility applications like traction inverters, bidirectional chargers and onboard energy management. The students will learn different circuit topologies and basic control structures for power electronic circuits. The interaction between the power grid and electric vehicles will be discussed.
Examination achievement
Oral examination *(Prüfungsgespräch)*, approx. 30 min. The examination takes place at the end of the winter semester.
Course achievement
none

Grading
The module grade is calculated 100% from the final oral exam.
Examination weight
■ Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
Usability
Wahlmodul für Studierende des Studiengangs ■ Master of Science in Sustainable Systems Engineering - Energiesysteme / Energy Systems ■ Master of Science Mikrosystemtechnik, PO 2018, concentration areas Circuits & Systems, Sensors & Actuators, Personal Profile ■ Master of Science Microsystems Engineering, PO 2018, concentration areas Circuits & Systems, Sensors & Actuators, Personal Profile ■ Master of Science Mikrosystemtechnik, PO 2021, Vertiefungsrichtung Circuits & Systems ■ Master of Science Microsystems Engineering, PO 2021, concentration area Circuits & Systems ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Circuits and Systems

↑

Name of module	Number of module
Leistungselektronik für die Elektromobilität/Power Electronics for E-Mobility	11LE50MO-4106 PO 2021
Veranstaltung	
Leistungselektronik für die Elektromobilität - Vorlesung	
Event type	Number
Vorlesung	11LE68V-4106
Organizer	
Institut für Nachhaltige Technische Systeme	

ECTS-Points	3.0
Workload	Attendance: 24 h lecture + 6 h exercise = 30 h Self-study: 60 h 90 h
Attendance	30 h
Independent study	60 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Power Electronics for E-Mobility applications:

- Conductive and inductive chargers for electric vehicles
- Traction inverters and electric motors
- DC/DC converters for onboard energy management
- Control of grid connected inverters
- E-Mobility as an instrument for a better grid integration of renewable energies

Exercises/Tutorials are included in the lecture (3 exercises x 2 h, conducted by Akshay Mahajan in the winter term 2021/22).

- Simulation of basic topologies and control structures (Simulationsoftware: PLECS)

Qualification

See module

Examination achievement

See module

Course achievement

See module

Literature

- Teodorescu R., Liserre M., Rodriguez P.; Grid Converters for Photovoltaic and Wind Power Systems, Wiley-IEEE, 2011

Compulsory requirement
Recommended requirement
Module *Energy Efficient Power Electronics* (only summer term!); Basic Knowledge in (Power) Electronics and Control
Teaching method
Lecture with embedded exercise
Recommendation
This course is **not** available for exchange students.

↑

Name of module	**Number of module**
Leistungselektronik für Photovoltaik und Windenergie / Power Electronics for Photovoltaics and Wind Energy	11LE50MO-4107 PO 2021
Responsible	
Prof. Dr. Anke Weidlich	
Organizer	
Institut für Nachhaltige Technische Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Attendance	28 Stunden
Independent study	62 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
Knowledge in Electrical Components (Semiconductors, Inductors, Capacitors)

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Leistungselektronik für Photovoltaik und Windenergie - Vorlesung	Vorlesung		3.0	2.0	90 h

Qualification
Power electronics circuits convert the DC power of PV modules to grid compatible AC power. Wind turbines produce AC power with variable frequency, which has to be converted to AC with grid frequency. The commonly used hardware topologies of power electronic converters for renewable energies are shown and explained in detail. Additional aspects like MPP-tracking, supply of reactive power, low voltage ride through (LVRT) etc. are discussed.
Examination achievement
Oral examination, duration: approx. 30 min.
Course achievement
None

Grading
The module grade is calculated 100% from the final oral exam.
Examination weight
■ Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
Usability
Compulsory elective module for students of the study program ■ Master of Science in Sustainable Systems Engineering, Energiesysteme / Energy Systems ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systeme

↑

Name of module	Number of module
Leistungselektronik für Photovoltaik und Windenergie / Power Electronics for Photovoltaics and Wind Energy	11LE50MO-4107 PO 2021
Veranstaltung	
Leistungselektronik für Photovoltaik und Windenergie - Vorlesung	
Event type	Number
Vorlesung	11LE68V-4107
Organizer	
Institut für Nachhaltige Technische Systeme	

ECTS-Points	3.0
Workload	90 h
Attendance	30 h
Independent study	60 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Solar Module Integrated Electronics
- Single Phase String Inverters
- Three Phase String Inverters
- Battery Chargers and Off-Grid Inverters
- PV System Technology
- Frequency converters for Wind Energy

Examination achievement

See module

Course achievement

See module

Literature

- Robert W. Erickson, Dragan Marksimovic: Fundamentals of Power Electronics
- Mohan, Undeland, Robbins: Power Electronics

http://nptel.ac.in/courses/Webcourse-contents/IIT%20Kharagpur/Power%20Electronics/New_index1.html
https://en.wikipedia.org/wiki/DC-to-DC_converter
https://en.wikipedia.org/wiki/Power_inverter
https://en.wikipedia.org/wiki/Variable-frequency_drive

Compulsory requirement

Module *Energy Efficient Power Electronics* (only summer term!)

Recommended requirement
Knowledge in Electrical Components (Semiconductors, Inductors, Capacitors)
Teaching method
Lecture

↑

Name of module	**Number of module**
Mikroakustische Wandler / Micro Acoustical Transducers	11LE50MO-5257 PO 2021
Responsible	
Prof. Dr.-Ing. Alfons Dehe	
Organizer	
Institut für Mikrosystemtechnik Smart Systems Integration	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	in jedem Semester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Mikroakustische Wandler / Micro Acoustical Transducers	Vorlesung		3.0	2.0	90 hours

Qualification
This lecture introduces into the fundamentals of air born sound propagation and effects in conjunction with the interaction of MEMS systems. You familiarize with the principles of sound transducers such as microphones and microspeakers as well as their design, key performance parameters and fabrication. Silicon microphones are the most widely spread MEMS systems worldwide and keep growing in volume as well as applications. As a role model for an integrated system, the Si microphone development will open insight into the needs and constraints of consumer product development.
Examination achievement
Oral examination (20 minutes)
Course achievement
None

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	**Number of module**
Mikroakustische Wandler / Micro Acoustical Transducers	11LE50MO-5257 PO 2021
Veranstaltung	
Mikroakustische Wandler / Micro Acoustical Transducers	
Event type	Number
Vorlesung	11LE50V-5257
Organizer	
Institut für Mikrosystemtechnik Smart Systems Integration	

ECTS-Points	3.0
Workload	90 hours
Attendance	28 hours
Independent study	62 hours
Hours of week	2.0
Recommended semester	
Frequency	in jedem Semester
Pflicht/Wahlpflicht (P/WP)	

Contents
Lectures on: 1. Acoustic field and effects 2. General acoustical transducer principles 3. Modeling in acoustical, mechanical and electrical domain 4. Example of capacitive transducer and identification of key performance parameters 5. Different MEMS microphone concepts and their pros and cons 6. MEMS fabrication 7. Aspects of assembly and packaging 8. Acoustical measurement techniques 9. From microphone to microspeaker 10. Future trends 11. Applications of MEMS acoustical transducers
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement
None
Recommended requirement
None
Teaching method
Will be taught in English if there is at least one international participant.

↑

Name of module	**Number of module**
Mikrocomputertechnik/ Microcontroller Techniques - Praktikum	11LE50MO-760MScPr PO 2021
Responsible	
Prof. Dr. Stefan Rupitsch	
Organizer	
Institut für Mikrosystemtechnik Elektr. Messt. u. Eingebettete Sys.	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
Basic knowledge of electronics, binary arithmetics, C programming and the structure of microcontrollers.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Mikrocomputertechnik / Microcontroller Techniques - Praktikum	Praktikum		3.0	2.0	90 hours

Qualification
Students have obtained practical knowledge in using microcontrollers. By means of Texas Instrument's MSP430 microcontroller as an example, the students have learned the basics of low-level C programming and the usage of the most important peripheral modules such as I/Os, analog-to-digital converters, timers, etc. Finally, the students will be able to use microcontroller hard- and software concepts in their own projects.
Examination achievement
The exam consists in the submission of 9 practically-oriented exercise sheets throughout the semester. The grade of each exercise sheet is 1/9 of the final module grade. Explanation: This lab course is a hands-on course with an emphasis on the continuous development of microprocessor programming. Since these development processes represent the essential course work, their results will be collected and evaluated throughout the semester. In case of failure to hand in one of these deliverables due to illness, an extention of the deadline will be granted.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	Number of module
Mikrocomputertechnik/ Microcontroller Techniques - Praktikum	11LE50MO-760MScPr PO 2021
Veranstaltung	
Mikrocomputertechnik / Microcontroller Techniques - Praktikum	
Event type	Number
Praktikum	11LE50P-760MScPr
Organizer	
Technische Fakultät Institut für Mikrosystemtechnik Elektr. Messt. u. Eingebettete Sys.	

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Based on a custom hardware learning platform being developed by the Laboratory for Electrical Instrumentation and using a TI MSP430G2553 microcontroller, the students will gain insight into the following topics:
• Low-level C programming
• Hard- and software debugging
• Using microcontroller inputs and outputs
• Using internal and external peripheral hardware
• Using communication interfaces
The students will autonomously perform the practical exercises at home. This is facilitated by a hardware kit containing the microcontroller board as well as required equipment, which can be obtained from the library of the technical faculty (the kit is labeled “µ-Controller-Praktikum I”). The support is given by the tutors on the ILIAS online platform, laboratory lessons will only be given as required. Mandatory events are two short colloquiums (students have to explain their exercise solution to a tutor twice, the deadlines and appointments will be made on demand).

Examination achievement

see module details

Course achievement

none

Literature

MSP430 Microcontroller Basics: John H. Davies
Electronic Circuits - Handbook for Design and Application: Tietze, Schenk, Gamm

Compulsory requirement
None
Recommended requirement
Basic knowledge of electronics, binary arithmetics, C programming and the structure of microcontrollers.
Recommendation
The successful completion of this module is mandatory for the participation in the module “Advanced Laboratory in Microcontroller”.

↑

Name of module	**Number of module**
Model Predictive Control and Reinforcement Learning	11LE50MO-5720 PO 2021
Responsible	
Prof. Dr. Joschka Bödecker Prof. Dr. Moritz Diehl	
Organizer	
Institut für Mikrosystemtechnik Systemtheorie Institut für Informatik Neurorobotik	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
None
Recommended requirement
Prior Knowledge in Systems and Control, State Space Control Systems, Numerical Optimization, Numerical Optimal Control, Reinforcement Learning and Machine Learning is an advantage.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Model Predictive Control and Reinforcement Learning	Vorlesung		3.0	1.0	90 h
Model Predictive Control and Reinforcement Learning	Übung			1.0	

Qualification
Participants understand the concepts of model predictive control (MPC) and reinforcement learning (RL) as well the similarities and differences between the two approaches. They are able to apply the methods to practical optimal control problems from science and engineering.
Examination achievement
Towards the end of the course, participants will work on application projects which apply at least one of the MPC and RL methods to self-chosen application problems from any area of science or engineering. The results of the projects, that can be performed in teams, will be presented in a public presentation on the last day of the course and a short report to be submitted two weeks after the course. The final course grade (Prüfungsleistung) is based on the final project report.

Course achievement
A mandatory requirement for passing (Studienleistung) is based on the written microexam at the end of the course.
Usability
As compulsory elective in ■ M.Sc. Microsystems Engineering (PO 2021) and M.Sc. Mikrosystemtechnik (PO 2021), Concentrations Area: Circuits and Systems ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Circuits and Systems Also: ■ Concentration course for MSc. Embedded Systems Engineering (PO 2012) in the concentration areas Robotic and Computer Vision, Zuverlässige Eingebettete Systeme, Circuits and Systems, Design and Simulation. ■ Concentration course for MSc. Microsystems Engineering (PO 2018) in the concentration areas Circuits and Systems, Design and Simulation. ■ Concentration course for MSc. Mikrosystemtechnik (PO 2018) students in the concentration areas Circuits and Systems, Design and Simulation.

↑

Name of module	**Number of module**
Model Predictive Control and Reinforcement Learning	11LE50MO-5720 PO 2021
Veranstaltung	
Model Predictive Control and Reinforcement Learning	
Event type	Number
Vorlesung	11LE50V-5720_PO20091
Organizer	
Institut für Mikrosystemtechnik Systemtheorie Institut für Informatik Neurorobotik	

ECTS-Points	3.0
Workload	90 h
Attendance	26
Independent study	64
Hours of week	1.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
Lectures cover: optimal control problem formulations (constrained, infinite horizon, discrete time, stochastic, robust), dynamic programming, model predictive control formulations and stability, reinforcement learning formulations, MPC algorithms, RL algorithms, similarities and differences between MPC and RL Towards the end of the course, participants will work on application projects which apply at least one of the MPC and RL methods to self-chosen application problems from any area of science or engineering. The results of the projects, that can be performed in teams, will be presented in a public presentation on the last day of the course and a short report to be submitted two weeks after the course. The report will determine the final grade of the course.
Examination achievement
see module details
Course achievement
see module details
Literature
“Reinforcement Learning: An Introduction” by Richard S. Sutton and Andrew G. Barto “Model Predictive Control: Theory, Computation, and Design” by James B. Rawlings, David Q. Mayne, and Moritz M. Diehl “Optimal Control and Reinforcement Learning" by Dimitri Bertsekas
Compulsory requirement
None

Recommended requirement
Prior Knowledge in Systems and Control, State Space Control Systems, Numerical Optimization, Numerical Optimal Control, Reinforcement Learning and Machine Learning is an advantage.

↑

Name of module	**Number of module**
Model Predictive Control and Reinforcement Learning	11LE50MO-5720 PO 2021
Veranstaltung	
Model Predictive Control and Reinforcement Learning	
Event type	Number
Übung	11LE50Ü-5720_PO20091
Organizer	
Institut für Mikrosystemtechnik Systemtheorie Institut für Informatik Neurorobotik	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
Computer exercises based on MATLAB, Octave or Python will accompany the lectures in order to gain hands-on-knowledge on method of MPC and RL
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Modellprädiktive Regelung für erneuerbare Energiesysteme	11LE50MO-5723 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden / hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine | none
Recommended requirement
Prior knowledge in the following fields is an advantage: - Mathematics 1 and 2 for engineers (or basic linear algebra and calculus courses) - Linear systems theory - State space control - Numerical optimization - Modeling and system identification (MSI)

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Modellprädiktive Regelung für erneuerbare Energiesysteme	Vorlesung		3.0	2.0	90 Stunden

Qualification
The students will be familiar with the control-oriented modelling of different renewable energy systems. They can analyze and formulate linear and nonlinear model predictive control problems for these systems. They can use state-of-the-art software tools to efficiently compute a numerical solution to these problems.
Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes)
Course achievement
The course work is completed if students pass the mid-term online quiz.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Concentration Area Circuits and Systems

↑

Name of module	Number of module
Modellprädiktive Regelung für erneuerbare Energiesysteme	11LE50MO-5723 PO 2021
Veranstaltung	
Modellprädiktive Regelung für erneuerbare Energiesysteme	
Event type	Number
Vorlesung	11LE50V-5723 PO 2021
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	32 Stunden
Independent study	58 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Model predictive control (MPC) is an advanced control technique that is able to flexibly deal with complex, multivariable systems with high performance demands operating under constraints.
MPC becomes more and more important in the field of renewable energy systems because it can account systematically for the complex and varying system demands while maximizing resource efficiency during operation.

During the lectures the following topics will be treated:
- Introduction to MPC for energy systems
- Overview of traditional and advanced control concepts
- Basics of simulation and optimization
- Fundamentals and solution methods of linear MPC
- Fundamentals and solution methods of nonlinear MPC
- Modeling and control of building energy systems
- Modeling and control of solar energy plants
- Modeling and control of wind energy plants

Bi-weekly voluntary exercises will be provided in order to help the student to understand the theory better.

Examination achievement

see module details

Course achievement

see module details

Literature

"Model Predictive Control: Theory, Computation, and Design" by James B. Rawlings, David Q. Mayne, and Moritz M. Diehl

Compulsory requirement
None
Recommended requirement
Prior knowledge in the following fields is an advantage: - Mathematics 1 and 2 for engineers (or basic linear algebra and calculus courses) - Linear systems theory - State space control - Numerical optimization - Modeling and system identification (MSI)

↑

Name of module	Number of module
MST Design Lab II for Microsystems Engineering	11LE50MO-7005 PO 2021
Responsible	
Prof. Dr. Peter Woias	
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	180 hours
Recommended semester	2
Duration	1 term
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none
Recommended requirement
Succesful completion of either the module "MST Design Lab I" (M.Sc. Microsystems Engineering) or "Konstruktionsmethodik" (B.Sc. Mikrosystemtechnik).

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
MST Design Lab II for Microsystems Engineering - Praktische Übung	Praktikum		3.0	4.0	180 hours

Qualification
The MST Design Lab II is an add-on to the lectures "MST Design Lab I" in the International Master course "Microsystems Engineering" or the lecture "Konstruktionsmethodik" in the German Bachelor course "Mikrosystemtechnik". It is not part of the mandatory curriculum, but can be taken by students as elective course only. The aim of this lab course is to build the product ideas designed in the above-mentioned courses in hardware, to achieve a working device. They may also, as a newly formed team, bring in their own idea for a product development. During this course, students will develop skills in project management, task distribution, time scheduling, project execution, report writing and presenting their results in an oral presentation. They also learn to work with appropriate hardware and software tools (e.g. 3D printing, laser machining, µC programming, soldering, PCB board design software...). To start in this module, students have to re-form groups by themselves or start as the project team formed before in the above-mentioned courses. This design lab is organized by one microsystems laboratory of the faculty, however tutoring is happening per group by all microsystems labs on a freelance basis, i.e. every lab and professor decides per semester, whether a tutoring will be offered or not. It is then an essential part of the teaching goals that the students convince a lab to act as a host for their project. If successful, the project teams receive a limited financial fund for their project and will use capabilities available in the respective host laboratories. Usually, a tutor is assigned to every group to guide the teams throughout the semester.

Usability
Students of the M.Sc. programmes Microsystems Engineering (PO 2021) can select this module in the concentration area Circuits and Systems (Schaltungen und Systeme).

↑

Name of module	**Number of module**
MST Design Lab II for Microsystems Engineering	11LE50MO-7005 PO 2021
Veranstaltung	
MST Design Lab II for Microsystems Engineering - Praktische Übung	
Event type	Number
Praktikum	11LE50prÜ-7005_PO 20091
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	

ECTS-Points	3.0
Workload	180 hours
Attendance	52 hours
Independent study	128 hours
Hours of week	4.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The aim of this lab course is to build the product ideas designed in the lectures "MST Design Lab I" in the International Master course "Microsystems Engineering" or the lecture "Konstruktionsmethodik" in the German Bachelor course "Mikrosystemtechnik", to achieve a working device.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
Recommended requirement
Succesful completion of either the module "MST Design Lab I" (M.Sc. Microsystems Engineering) or "Konstruktionsmethodik" (B.Sc. Mikrosystemtechnik).

↑

Name of module	**Number of module**
Numerische Optimale Steuerung - Projekt / Numerical Optimal Control in Engineering - Project	11LE50MO-5250 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Numerical Optimal Control - Project	Projekt		3.0	1.0	90 hours

Qualification
Students will be able to independently program, analyze, and apply numerical methods of optimal control.
Examination achievement
Submission of a report incl. a documented computer code.
Course achievement
Oral presentation
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	**Number of module**
Numerische Optimale Steuerung - Projekt / Numerical Optimal Control in Engineering - Project	11LE50MO-5250 PO 2021
Veranstaltung	
Numerical Optimal Control - Project	
Event type	Number
Projekt	11LE50Pro-5250
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	3.0
Workload	90 hours
Attendance	14 hours
Independent study	76 hours
Hours of week	1.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
The project consists of implementing one or more self-selected optimal control methods on the computer and applying them to one or more self-selected application problems. The focus may be more on algorithms and performance comparisons or on modeling a specific problem. The result of the project is a documented computer code, a report, and a public presentation.
Examination achievement
see module details
Course achievement
see module details
Literature
http://syscop.de/teaching/
Compulsory requirement
None
Recommendation
It is strongly recommended to attend the Numerical Optimal Control lecture offered in the same semester.

↑

Name of module	**Number of module**
Numerische Optimierung / Numerical Optimization	11LE50MO-5243 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Numerische Optimierung / Numerical Optimization	Vorlesung		6.0	4.0	180 hours
Numerische Optimierung / Numerical Optimization	Übung			2.0	

Qualification
The students know different types of optimization problems and can discuss their theoretical background and implement and analyze numerical methods for solving them.
Examination achievement
Written exam (180 minutes)
Course achievement
The course work is completed if students pass the mid-term online quiz.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	Number of module
Numerische Optimierung / Numerical Optimization	11LE50MO-5243 PO 2021
Veranstaltung	
Numerische Optimierung / Numerical Optimization	
Event type	Number
Vorlesung	11LE50V-5243
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	6.0
Workload	180 hours
Attendance	90 hours
Independent study	90 hours
Hours of week	4.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The course is divided into four major parts:
1. Fundamental Concepts of Optimization: Definitions, Types, Convexity, Duality
2. Unconstrained Optimization and Newton Type Algorithms: Stability of Solutions, Gradient and Conjugate Gradient, Exact Newton, Quasi-Newton, BFGS and Limi- ted Memory BFGS, and Gauss-Newton, Line Search and Trust Region Methods, Algorithmic Differentiation
3. Equality Constrained Optimization Algorithms: Newton Lagrange and Generalized Gauss-Newton, Range and Null Space Methods, Quasi-Newton and Adjoint Based Inexact Newton Methods
4. Inequality Constrained Optimization Algorithms: Karush-Kuhn-Tucker Conditions, Linear and Quadratic Programming, Active Set Methods, Interior Point Methods, Se- quential Quadratic and Convex Program- ming, Quadratic and Nonlinear Parametric Optimization

Examination achievement

see module details

Course achievement

see module details

Literature

1. Jorge Nocedal and Stephen J. Wright, Numerical Optimization, Springer, 2006
2. Amir Beck, Introduction to Nonlinear Optimization, MOS-SIAM Optimization, 2014
3. Stephen Boyd and Lieven Vandenberghe, Convex Optimization, Cambridge Univ. Press, 2004

Compulsory requirement

None

Recommended requirement

Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

↑

Name of module	**Number of module**
Numerische Optimierung / Numerical Optimization	11LE50MO-5243 PO 2021
Veranstaltung	
Numerische Optimierung / Numerical Optimization	
Event type	Number
Übung	11LE50Ü-5243
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
In der Übung werden die Inhalte der Vorlesung anhand theoretischer Beispielaufgaben sowie mit Rechnerübungen vertieft.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Mathematics 1 and 2 for Engineers or basic Linear Algebra and Calculus courses

↑

Name of module	**Number of module**
Numerische Optimierung Projekt / Numerical Optimization Project	11LE50MO-5244 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Numerische Optimierung / Numerical Optimization - Projekt	Projekt		3.0	1.0	90 hours

Qualification
Students will be able to independently program, analyze, and apply continuous optimization methods. The project consists of implementing one or more self-selected optimization methods on the computer and applying them to one or more self-selected application problems. The focus may be more on algorithms and performance comparisons or on modeling a specific problem. The result of the project is a documented computer code, a report, and a public presentation.
Examination achievement
Submission of a report incl. a documented computer code.
Course achievement
A short oral presentation at the end of the semester.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

↑

Name of module	**Number of module**
Numerische Optimierung Projekt / Numerical Optimization Project	11LE50MO-5244 PO 2021
Veranstaltung	
Numerische Optimierung / Numerical Optimization - Projekt	
Event type	Number
Projekt	11LE50Pr-5244
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	3.0
Workload	90 hours
Attendance	15 hours
Independent study	75 hours
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
None
Recommendation
It is strongly recommended to attend the Numerical Optimization lecture offered in the same semester.

↑

Name of module	**Number of module**
Rennautoregelung Praktikum / Race Car Control Laboratory	11LE50MO-5224 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
None
Recommended requirement
The lab course includes topics as part of the Race Car project (Simulation, Optimization and Control of small race cars). The project offers a large variety of project topics, students may be assigned topics meeting their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Rennautoregelung Praktikum / Race Car Control Laboratory	Praktikum		6.0	4.0	180 Stunden

Qualification
Aim of this lab course is to use the theoretical background for real applications in a scientific project. Finding creative solutions to problems as well as hands-on testing/verification of soft- and hardware will be part of the projects. The lab course will also offer experience of working in an international team.
Examination achievement
project report
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Circuits and Systems

↑

Name of module	**Number of module**
Rennautoregelung Praktikum / Race Car Control Laboratory	11LE50MO-5224 PO 2021
Veranstaltung	
Rennautoregelung Praktikum / Race Car Control Laboratory	
Event type	Number
Praktikum	11LE50P-5224
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	56 hours
Independent study	126 hours
Hours of week	4.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
Focus of the lab course is setting up a race track and control system for autonomous driving cars. The set up consists of a track, cars, a color camera, which is tracking the cars and a computer, controling the cars. The communication between the race cars and the computer will be carried out by hacking the remote control. The color camera can be seen as the sensor of the car, communicating its actual position to the computer. The course will be accompanied by weekly meetings with one or more team members working on complementary projects addressing the same real world control problem. In the last two to three weeks of the lab course, when the main project aims are achieved, the participants will start to work on a short report for documentation and give a final oral presentation to share their findings with all team members.
Examination achievement
Written composition and oral presentation of the project results.
Course achievement
None
Compulsory requirement
None
Recommended requirement
The lab course includes topics as part of the Race Car project (Simulation, Optimization and Control of small race cars). The project offers a large variety of project topics, students may be assigned topics meeting their interests and academic background. Prior studies of “Modelling and System Identification” and/or “Optimal Control and Estimation” are recommended.

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Name of module	**Number of module**
RF- und Mikrowellen Bauelemente und Schaltungen / RF- and Microwave Devices and Circuits	11LE50MO-5215 PO 2021
Responsible	
Prof. Dr. Rüdiger Quay	
Organizer	
Institut für Nachhaltige Technische Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
RF- und Mikrowellen Bauelemente und Schaltungen - Vorlesung	Vorlesung		3.0	2.0	90 h

Qualification
The students will be able to understand concepts, devices, design, and functioning of modern RF- and microwave transceiver subsystems. This includes the understanding of basic RF-concepts, passive and active devices, circuits, functionalities, their critical figures-of-merrit, and the inclusion into modules. The students will be competent to analyse passive and active RF-structures and circuits, which are relevant for any system with an RF-functionality. The competence includes the full understanding of a transmit/receive module needed for today’s communcation and sensing.
Examination achievement
Oral examination, duration: approx. 30 min.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Enginnering Concentration Area Circuits and Systems

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Name of module	**Number of module**
RF- und Mikrowellen Bauelemente und Schaltungen / RF- and Microwave Devices and Circuits	11LE50MO-5215 PO 2021
Veranstaltung	
RF- und Mikrowellen Bauelemente und Schaltungen - Vorlesung	
Event type	Number
Vorlesung	11LE68V-5215
Organizer	
Inst. f. Nachh. Technische Systeme Energieeff. Hochfrequenzelektronik	

ECTS-Points	3.0
Workload	90 h
Attendance	26 h
Independent study	64 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The lecture RF- and Microwave Devices and Circuits deals with the fundamentals of RF-devices and circuits. It comprises three parts: high-frequency/RF concepts and passive structures, active electronic RF-devices, and RF-circuits and modules. At the interface of modern electronics, dielectric wave propagation, circuit design, and advanced communication and sensing, advanced analysis and characterisation techniques are introduced in order to bridge the gap from modern electronics and modern passive RF-technology to the understanding of RF-communication and sensing systems. The methodologies of RF-analysis, design of devices and circuits, and their basic figures-of-merit, their modelling and characterisation are introduced along with the demonstration of their relevance to modern RF- components and microsystems. This also includes a discussion of the underlying technology and many examples supported by RF-design tools from the microwave oven to today's RF-applications in mobile communication in the iPod.
Examination achievement
See module
Course achievement
See module
Literature
RF- and Microwave passives ▪ Zinke/Brunswig, Hochfrequenztechnik, Band 1, Springer, 1999 RF-Devices ▪ U.K. Mishra, J. Singh, Semiconductor Device Physics And Design, Springer, 2007
Compulsory requirement
None

Recommended requirement
None
Teaching method
Electronic handout will be provided during the lecture. Visit to the Fraunhofer IAF.
Recommendation
Electronic handout will be provided during the lecture. Visit to the Fraunhofer IAF.

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Name of module	**Number of module**
RF- und Mikrowellen Schaltungen und Systeme / RF- and Microwave Circuits and Systems	11LE50MO-5232 PO 2021
Responsible	
Prof. Dr. Rüdiger Quay	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
RF- und Mikrowellen Schaltungen und Systeme - Vorlesung	Vorlesung		3.0	2.0	90 h

Qualification
The students will be able to understand, design and layout modern RF- and microwave components and systems by means of the electronic design environment Agilent Advanced Design System including the two- and three dimensional electromagnetic simulators Momentum and EMPro 3D. The detailed use of a complex RF-software environment is a dedicated target of this course. This includes the numerical analysis of complex passive and active devices, the design and layout of hybrid and integrated circuits, and their packaging and signal flow. The students are competent to design and layout passive and active RF-structures including packages and interconnects and circuits of relevance to everydays communication and sensing. The competence includes in-depth understanding and treatment of complex microwave systems and of general system design including the treatment of complex modulated signal flows.
Examination achievement
Oral examination, duration: approx. 30 min.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Concentration Area Circuits and Systems

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Name of module	**Number of module**
RF- und Mikrowellen Schaltungen und Systeme / RF- and Microwave Circuits and Systems	11LE50MO-5232 PO 2021
Veranstaltung	
RF- und Mikrowellen Schaltungen und Systeme - Vorlesung	
Event type	Number
Vorlesung	11LE68V-5232
Organizer	
Institut für Nachhaltige Technische Systeme	

ECTS-Points	3.0
Workload	90 h
Attendance	30 h
Independent study	60 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The lecture RF- and Microwave circuits and systems deals with the fundamentals and concepts of RF-circuits and systems. It comprises three parts: fundamental RF-concepts with focus on communications and sensing, more complex RF-circuits, and actual RF systems. At the interface of modern electronics, wave propagation, circuit design, and advanced communication and sensing, advanced analysis and characterisation techniques are introduced in order to bridge the gap from modern integrated circuits to the understanding of RF-communication and sensing systems with all aspects of frequency conversion, amplification, noise, distortion, and detection. The methodologies of RF-analysis, design of circuits, complex signal flows, their modelling and their characterisation are introduced along with the demonstration of their relevance to real RFcomponents and (micro)-systems. Typical applications include a mobile handset such as the SmartPhone, automotive radar, and wireless data communication links for high-data-rate transmission.
Examination achievement
See module
Course achievement
See module
Literature
RF- and Microwave passives ▪ Zinke/Brunswig, Hochfrequenztechnik, Band 1, Springer, 1999 Further literature for systems are presented during the lecture
Compulsory requirement
None

Recommended requirement
None
Teaching method
Electronic handout will be provided during the lecture. Visit to the Fraunhofer IAF.
Recommendation
No prior knowledge of the software is required.

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Name of module	Number of module
RF- und Mikrowellen Systeme - Design Kurs / RF- and Microwave Systems - Design Course	11LE50MO-5344 PO 2021
Responsible	
Prof. Dr. Rüdiger Quay	
Organizer	
Institut für Nachhaltige Technische Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
The prior or parallel participation in either module "RF- and microwave devices and circuits" or "RF- and microwave circuits and systems" is required. No prior knowledge of the software is required.
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
RF- und Mikrowellen Systeme - Design Kurs / RF- and Microwave Systems - Design Course	Praktikum		3.0	2.0	90 h

Qualification
The students will be enabled to understand, design and layout modern RF- and microwave components and systems by means of the electronic design environment Agilent Advanced Design System including the two- and three dimensional electromagnetic simulators Momentum and EMPro 3D. The detailed use of a complex RF-software environment is a dedicated target of this course. This includes the numerical analysis of complex passive and active devices, the design and layout of hybrid and integrated circuits, and their packaging and signal flow. The students will be competent to design and layout passive and active RF-structures including packages and interconnects and circuits of relevance to everydays communication and sensing. The competence includes in-depth understanding and treatment of complex microwave systems and of general system design including the treatment of complex modulated signal flows.
Examination achievement
The grade is calculated based on the average of the submitted exercises (5 out of 6). There is no exam.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems

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Name of module	Number of module
RF- und Mikrowellen Systeme - Design Kurs / RF- and Microwave Systems - Design Course	11LE50MO-5344 PO 2021
Veranstaltung	
RF- und Mikrowellen Systeme - Design Kurs / RF- and Microwave Systems - Design Course	
Event type	Number
Praktikum	11LE68P-5344
Organizer	
Inst. f. Nachh. Technische Systeme Energieeff. Hochfrequenzelektronik	

ECTS-Points	3.0
Workload	90 h
Attendance	26 h
Independent study	64 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The Design Course: RF- and Microwave Systems deals with the analysis and creation of RFdevices, circuits and systems. It comprises three aspects: the detailed electromagnetic design of high-frequency/RF passive and active structures, the modelling and layout and verification of active electronic RF-devices in circuit environments based on various semiconductor technologies, and the high-level combination of more complex microwave systems. This includes the simulation of printed circuit boards, of integrated circuits and of devices in package including RF-interconnects, and of behavioural system simulation. Advanced analysis of RF-problems, characterisation, modelling and linear and non-linear simulation techniques are introduced in order to combine knowledge from modern electronics (from various technologies such as silicon complementary MOS and GaAs), from component analysis, RF-circuit design principles, and system engineering. The examples include simple printed circuits boards, integrated circuits, advanced communication transceivers in mobile communication based on LTE and modern radar.
Examination achievement
See module
Course achievement
See module
Literature
■ Keysight Design System User Manual www.keysight.com ■ Script: Design Course: RF- and Microwave Systems, R. Quay, (will be provided at the beginning of the lecture)
Compulsory requirement
The prior or parallel participation in either module *RF- and microwave devices and circuits* or *RF- and microwave circuits and systems* is required. No prior knowledge of the software is required.

Recommended requirement
None

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Name of module	**Number of module**
Robot Mechanics	11LE50MO-5724 PO 2021
Responsible	
JProf. Dr. Edoardo Milana	
Organizer	
Institut für Mikrosystemtechnik Professur für Soft Machines	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden | hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine | none
Recommended requirement
Foundations in mechanics, calculus, geometry

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Robot Mechanics	Vorlesung		3.0	2.0	90 Stunden | hours

Qualification
This course provides students with the knowledge and tools needed to model and analyze robotic manipulators, with an emphasis on mechanical performance. Students will learn how to analyze robotic systems, model their kinematics and dynamics, and design manipulators based on operational requirements. Application of this knowledge includes designing, modeling, and evaluating robots using real-world examples. Students demonstrate their understanding by presenting real-world use cases and demonstrate their ability to select and evaluate robot types for specific manipulation tasks.
Examination achievement
Klausur | written exam
Course achievement
keine | none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Microsystems Engineering Concentrations Area Materials and Fabrication ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. in Sustainable Systems Engineering (PO 2021), Interdisciplinary Profile

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Name of module	Number of module
Robot Mechanics	11LE50MO-5724 PO 2021
Veranstaltung	
Robot Mechanics	
Event type	Number
Vorlesung	11LE50V-5724 PO 2021
Organizer	
Institut für Mikrosystemtechnik Professur für Soft Machines	

ECTS-Points	3.0
Workload	90 Stunden | hours
Attendance	64 Stunden | hours
Independent study	26 Stunden | hours
Hours of week	2.0
Recommended semester	2
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Kinematic chains, joints, mobility, types of manipulators, reference frames, forward kinematics, inverse kinematics, Jacobian, trajectory planning, dynamics
Qualification
This course provides students with the knowledge and tools needed to model and analyze robotic manipulators, with an emphasis on mechanical performance. Students will learn how to analyze robotic systems, model their kinematics and dynamics, and design manipulators based on operational requirements. Application of this knowledge includes designing, modeling, and evaluating robots using real-world examples. Students demonstrate their understanding by presenting real-world use cases and demonstrate their ability to select and evaluate robot types for specific manipulation.
Examination achievement
siehe Moduleebene | see module level
Course achievement
siehe Moduleebene | see module level
Literature
Bruno Siciliano, Lorenzo Sciavicco, Luigi Villani, and Giuseppe Oriolo. 2008. Robotics: Modelling, Planning and Control (1st. ed.). Springer Publishing Company, Incorporated.
Compulsory requirement
keine | none
Recommended requirement
Foundations in mechanics, calculus, geometry

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Name of module	Number of module
Sensor-Aktor-Schaltungstechnik	11LE50MO-5725 PO 2021
Responsible	
Prof. Dr. Peter Woias	
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden
Recommended semester	
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
Recommended requirement
Wissen und Kenntnisse der vermittelten Lehrmodule "Einführung in die Elektrotechnik" und "Messtechnik" des Bachelor-Studiengangs Mikrosystemtechnik, alternativ aus vergleichbaren Lehrveranstaltungen anderer Hochschulen. Vertiefte Grundkenntnisse zu elektronischen Bauelementen.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Sensor-Aktor-Schaltungstechnik	Vorlesung		6.0	2.0	180 Stunden
Sensor-Aktor-Schaltungstechnik	Übung			2.0	

Qualification
Das Modul vermittelt grundlegendes Wissen zur elektronischen Schaltungstechnik der signalverarbeitenden Elektronik für verschiedene Mikrosensoren und Mikroaktuatoren. Es werden in einer Abfolge von Kapiteln zunächst die Grundlagen einiger wesentlicher elektronischer Bauelemente und Funktionsgruppen vermittelt. Anschließend werden kapitelweise verschiedene Sensor- und Aktormechanismen kurz vorgestellt, gefolgt von einer Erläuterung der wichtigsten Schaltungskonzepte für ihren Betrieb. Die Übung vertieft den Lehrstoff anhand der Präsentation und Diskussion exemplarischer Designbeispiele von elektronischen Schaltungen.
Examination achievement
mündliche Prüfung

Course achievement
keine
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems

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Name of module	Number of module
Sensor-Aktor-Schaltungstechnik	11LE50MO-5725 PO 2021
Veranstaltung	
Sensor-Aktor-Schaltungstechnik	
Event type	Number
Vorlesung	11LE50V-5725
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Inhalte sind: • Einführung in elektronische Bauelemente und Funktionsblöcke (Diode, Bipolartransistor, Stromquellen, Stromspiegel, Bandgap-Referenz, Operationsverstärker) • Stromliefernde Sensoren (Photodiode, amperometrische Elektrode) • Spannungsliefernde Sensoren (Ionensensitiver Feldeffekttransistor) • Resistive Sensoren nach dem Wheatstone-Brückenprinzip (Druck, Beschleunigung) • Kapazitive Sensoren (Druck, Beschleunigung, Feuchte) • Kapazitive Aktoren (elektrostatisch, piezo)
Examination achievement
siehe Modulebene
Course achievement
keine
Literature
Tietze, Schenk, Gamm, Halbleiter-Schaltungstechnik, 15. Auflage, 2016, Springer, Berlin, ISBN 978-3-662-48354-1. Schrüfer, Reindl, Zagar, Elektrische Messtechnik, 11. Auflage, 2014, Carl-Vieweg-Verlag, München, ISBN 978-3-446-44208-5.
Compulsory requirement
Recommended requirement
Wissen und Kenntnisse der vermittelten Lehrmodule "Einführung in die Elektrotechnik" und "Messtechnik" des Bachelor-Studiengangs Mikrosystemtechnik, alternativ aus vergleichbaren Lehrveranstaltungen anderer Hochschulen.

Vertiefte Grundkenntnisse zu elektronischen Bauelementen.

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Name of module	**Number of module**
Sensor-Aktor-Schaltungstechnik	11LE50MO-5725 PO 2021
Veranstaltung	
Sensor-Aktor-Schaltungstechnik	
Event type	Number
Übung	11LE50Ü-5725
Organizer	
Institut für Mikrosystemtechnik Konstruktion von Mikrosystemen	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Die Übung vertieft den Lehrstoff anhand der Präsentation und Diskussion von exemplarischen Problemstellungen und Designbeispielen elektronischer Schaltungen.
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement

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Name of module	**Number of module**
State Space Control Systems	11LE50MO-5267 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden | hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
Keine | none
Recommended requirement
Students are expected to have an undergraduate knowledge in mathematics. It is furthermore recommended to have a good knowledge of differential equations, system theory and control. Kenntnisse/Kompetenzen aus Mathematik I und II werden VORAUSGESETZT. Kenntnisse aus Differentialgleichungen, Systemtheorie und Regelungstechnik werden EMPFOHLEN.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
State Space Control Systems	Vorlesung		6.0	3.0	180 hours
State Space Control Systems	Übung			1.0	

Qualification
The students understand the mathematical foundations of state space control systems and are able to design and use state space control systems in engineering applications.
Examination achievement
Written exam (120 minutes)
Course achievement
none
Recommendation
Work on the weekly exercise sheets and participation in the exercises is voluntary.

Usability
As compulsory elective in ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Circuits and Systems ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Microsystems Engineering, Concentration area Circuits and Systems Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering Wahlpflichtmodul für Studierende des Studiengangs ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik ■ B.Sc. in Informatik (PO 2018)

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Name of module	Number of module
State Space Control Systems	11LE50MO-5267 PO 2021
Veranstaltung	
State Space Control Systems	
Event type	Number
Vorlesung	11LE50V-5267-
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	3.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
Review of linear system theory in continuous time and ordinary differential equations; nonlinear and linear systems; discrete time and continuous time systems; eigenvalues and stability; Lyapunov functions; controllability, stabilizability, observability and detectability; control and observer normal form, Kalman normal form; pole placement, linear quadratic regulator (LQR); Luenberger observer, Kalman filter (KF); linear quadratic Gaussian (LQG) control and separation principle; disturbance modelling and offset free control; model predictive control (MPC); robustness; Extended and Unscented Kalman Filter (EKF/UKF); moving horizon estimation (MHE)
Examination achievement
see module details
Course achievement
see module details
Literature
■ Karl J. Åström and Richard M. Murray, Feedback Systems, Princeton University Press, 2011 ■ Stengel, R. Optimal Control and Estimation, Dover Publications, 1994 ■ S. Skogestad, I. Postlethwaite: Multivariable Feedback Control. Analysis and Design. Chichester/ New York, 2006. ■ G.F. Franklin, J.D. Powell, A. Emami-Naeini: Feedback Control of Dyna- mic Systems, Pearson (ISBN-13: 978-0-13-601969-5) Rawlings, J. B., Mayne, D. Q., and Diehl, M. M. Model Predictive Control: Theory, Computation, and Design, 2nd edition ed. Nob Hill, 2017.
Compulsory requirement
None

Recommended requirement
Students are expected to have an undergraduate knowledge in mathematics. It is furthermore recommended to have a good knowledge of differential equations, system theory and control. Kenntnisse/Kompetenzen aus Mathematik I und II werden VORAUSGESETZT. Kenntnisse aus Differentialgleichungen, Systemtheorie und Regelungstechnik werden EMPFOHLEN.

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Name of module	**Number of module**
State Space Control Systems	11LE50MO-5267 PO 2021
Veranstaltung	
State Space Control Systems	
Event type	Number
Übung	11LE50Ü-5267
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
The weekly exercise sheets allows students to apply their acquired knowledge. During the voluntary weekly exercise sessions the content of both the lecture and the exercise sheets will be discussed in-depth and consolidated.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Students are expected to have an undergraduate knowledge in mathematics. It is furthermore recommended to have a good knowledge of differential equations, system theory and control. Kenntnisse/Kompetenzen aus Mathematik I und II werden VORAUSGESETZT. Kenntnisse aus Differentialgleichungen, Systemtheorie und Regelungstechnik werden EMPFOHLEN.

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Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine | none
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Wearable and Implantable Computing (WIC)	Vorlesung		6.0	2.0	180 Stunden / Hours
Wearable and Implantable Computing (WIC)	Übung			2.0	

Qualification
Students are able to ■ Understand design concepts and apply/analyse wearable and implantable system design methods. ■ Analyse physical principles, select and optimise on-body energy harvesting and power management techniques. ■ Create context recognition and energy-efficient pattern analysis pipelines using sparse sampling and pattern processing methods. ■ Build wearable system prototypes and apply system evaluation methods, including design for biocompatibility.

Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) If there are too many students for a reasonably organized oral exam, it will be held as a written exam instead, announced well in advance.
Course achievement
Durchführung von Versuchen und Ergebnisprotokoll | Execution of experiments and written report of results
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung **|** Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science **OR** in Microsystems Engineering Concentrations Area Circuits and Systems/Biomedical Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems/Biomedical Engineering ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme/Biomedizinische Technik Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

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Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
Veranstaltung	
Wearable and Implantable Computing (WIC)	
Event type	Number
Vorlesung	11E13V-1402_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The course provides students with a comprehensive overview and in-depth skills on system design of sensor-based wearable and implantable computing systems. Course covers frequent sensors and actuators and their system integration, context recognition methods and selected algorithms, powering and energy management concepts (task scheduling, sparse sampling, and on-demand signal processing), energy harvesting methods, and system design topics (flexible electronics, electronics textile integration, multiprocess additive manufacturing), as well as principles of system validation.
Examination achievement
see module details
Course achievement
see module details
Literature
Up-to-date literature recommendations are provided during the lectures.
Compulsory requirement
None
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
Veranstaltung	
Wearable and Implantable Computing (WIC)	
Event type	Number
Übung	11E13Ü-1402_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Student groups will investigate concrete cases including context recognition, energy-efficient signal processing, and digital design of wearable systems. A wearable device prototype will be realised per student group.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

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Name of module	**Number of module**
Windenergiesysteme / Wind Energy Systems	11LE50MO-5256 PO 2021
Responsible	
Prof. Dr. Moritz Diehl	
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
None
Recommended requirement
Undergraduate knowledge in physics, mathematics as well as in systems and control.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Windenergiesysteme / Wind Energy Systems	Vorlesung		6.0	3.0	180 hours

Qualification
Students understand the physical principles of wind energy and the technology of modern wind energy systems.
Examination achievement
Written exam (180 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentration Area Circuits and Systems ■ M.Sc. Informatik / Computer Science (PO 2020), in Spezialvorlesung | Specialization Courses **Important note for M.Sc. Informatik / Computer Science:** This module is available as both ■ a specialization lecture in Computer Science (with a graded assessment / Prüfungsleistung) ■ as a course in the application area Applied Bioinformatics (as pass/fail course / Studienleistung) (see according module in online module handbook / planner of studies) Take care during the booking process, as that will define the category in which the course is considered. **You can't change the category afterwards!** So, you can't change it from PL to SL or vice versa.

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Name of module	**Number of module**
Windenergiesysteme / Wind Energy Systems	11LE50MO-5256 PO 2021
Veranstaltung	
Windenergiesysteme / Wind Energy Systems	
Event type	Number
Vorlesung	11LE50V-5256
Organizer	
Institut für Mikrosystemtechnik Systemtheorie	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 hours
Independent study	128 hours
Hours of week	3.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
Global wind energy resource - aerodynamic principles of wind turbines - design of modern wind turbines - control of modern wind turbines - the electrical system of wind turbines - alternative concepts and high-altitude wind energy.
Examination achievement
See module level
Course achievement
See module level
Literature
"Wind Energy Handbook" by T. Burton, N. Jenkins, D. Sharpe, E. Bossanyi, 2nd edition, Wiley, 2011
Compulsory requirement
Recommended requirement
Undergraduate knowledge in physics, mathematics as well as in systems and control.

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Name of module	Number of module
Zuverlässigkeitstechnik / Reliability Engineering	11LE50MO-5214 PO 2021
Responsible	
Prof. Dr. Jürgen Wilde	
Organizer	
Institut für Mikrosystemtechnik Aufbau- u. Verbindungstechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Zuverlässigkeitstechnik / Reliability Engineering - Vorlesung	Vorlesung		3.0	1.0	90 hours
Zuverlässigkeitstechnik / Reliability Engineering - Übung	Übung			1.0	

Qualification
The first qualification target is an understanding of terminology for dependability, reliability and safety in an engineering context. To that purpose quantitative definitions are given, and a mathematical understanding of the statistical basics of reliability engineering are acquired. A next step is the comprehension of the reliability of single mechanical and electronic components. To that purpose the fundamentals of fatigue and fracture mechanics will first be learned, followed by the testing and failure modelling of electronic devices. This allows to understand device degradation by environmental failure causes and to model stress-induced failures and reliability. By the combination of several elements systems are generated. In order to predict the reliability and to validate the safety of systems, risk analyses are treated. These comprise reliability block-diagrams, failure-rate analyses, fault-tree-analyses, the state-space-method, failure-mode-and-effects-analysis, and Markoff analysis. The student will also gain specific knowledge in fields like software dependability, dependability of repairable systems, and functional safety. The understanding of the respective techniques, also based on industrial standards gives the basic capabilities in order to develop safe systems. Application fields like automotive engineering, medical implants, or aerospace technology are of high relevance. In this way the lecture provides the basis for the understanding of state-of-the-art techniques and concepts of reliability engineering.

Examination achievement
Oral exam (30 minutes)
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), in MIcrosystems Engineering Concentration Area Circuits and Systems

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Name of module	Number of module
Zuverlässigkeitstechnik / Reliability Engineering	11LE50MO-5214 PO 2021
Veranstaltung	
Zuverlässigkeitstechnik / Reliability Engineering - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5214
Organizer	
Institut für Mikrosystemtechnik Aufbau- u. Verbindungstechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- 1. Definitions
- 1.1 Quality, dependability, reliability and safety
- 1.2 Benchmarks for dependability, availability und lifetime
- 1.3 Statistical description of reliability
- 2. Dependability of mechanical systems
- 2.1 Example 1: The ICE-crash at Eschede
- 2.2 Loads on mechanical components
- 2.3 Risk factors: notches and cracks
- 2.4 Fatigue - Woehler's S-N-curve concept
- 2.5 Computation of operational strength
- 3. Reliability of electronic hardware
- 3.1 Automotive electronics: architecture, requirements and quality level
- 3.2 Reliability of electronic devices, data
- 4. Reliability data-bases
- 5. Reliability of systems
- 5.1 Reliability block-diagram (failure-rate analysis)
- 5.2 Overview of failure mode analyses
- 5.3 Fault tree analysis (FTA)
- 5.4 State-Space: A general method to compute Rs(t) and Fs(t)
- 6. Reliability of repairable systems
- 6.1 Definitions
- 6.2 Repair rate
- 6.3 Availability
- 6.4 Markov-Chains and Markov-Processes
- 7. Software reliability
- 7.1 Examples of software-induced accidents
- 7.2 Probability of software faults
- 7.3 Reliability models for software
- 7.4 Misjudgements concerning software use

■ 8. Human factors ■ 9. Pre-requisites for development processes ■ 10. Standards and legislation for medical devices
Examination achievement
see module details
Course achievement
none
Literature
Short lecture notes and data files with existing ANSYS macros.
Compulsory requirement
None
Recommended requirement
Basic understanding in mathematics (statistics) as well as materials sciences.

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Name of module	**Number of module**
Zuverlässigkeitstechnik / Reliability Engineering	11LE50MO-5214 PO 2021
Veranstaltung	
Zuverlässigkeitstechnik / Reliability Engineering - Übung	
Event type	Number
Übung	11LE50Ü-5214
Organizer	
Institut für Mikrosystemtechnik Aufbau- u. Verbindungstechnik	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
See module details
Course achievement
None
Compulsory requirement
None
Recommended requirement
See lecture

↑

Name of module	**Number of module**
Study Project in Concentration Circuits and Systems	11LE50MO-SP MSE CS
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Organizer	
Institut für Mikrosystemtechnik Professur für Soft Machines	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	270 Stunden /hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
keine | none
Recommended requirement
allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Ingenieurswissenschaften, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general fundamental mathematical knowledge, practical and theoretical foundations in Engineering Sciences, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload

Qualification
In this module students get involved in the actual research process of the chosen work group/chair in the area of Circuits and Systems. Depending on their personal field of interest and their expertise in various research and teaching areas offered at the Department of Microsystems Engineering, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work experimentally and constructively in projects. Students acquire the ability to familiarize themselves with new engineering problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be trained.
Examination achievement
Depending on the specific project: written research paper or creation of demonstrators including a sufficient documentation or presentation and subsequent discussion

Course achievement
Regular attendance in (team) discussions or meetings with the supervisor. Self- organizing the given tasks, doing background research, presentation of results
Recommendation
Language is usually English, but might be negotiable (changed to German). Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.)

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Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
Responsible	
JProf. Dr. Alwin Stefan Daus	
Organizer	
Institut für Mikrosystemtechnik Sensoren	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
Basic knowledge on semiconductor physics and semiconductor devices. Having completed the module micro-electronics before taking this module is recommended.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Memory Device Technology	Vorlesung		6.0	2.0	180 Stunden / hours
Memory Device Technology	Übung			2.0	

Qualification
After completion of the module, - ■ the students know various classical memory and storage device types, technologies and working principles. ■ the students can explain the working principle of various emerging memory device types. ■ the students know about the different memory performance parameters, how they are measured and how different memory device technologies compare in those metrics ■ the students know how the physical integration and realization of different memory device types is realized ■ the students can explain limitations of different memory device technologies ■ the students can explain how the basic material properties of each memory device type enable and affect the memory behavior ■ the students can explain how emerging memristive devices are beneficial to enable in-memory computing and neuromorphic hardware

Examination achievement
Prüfungsgespräch / oral examination
Course achievement
Referat, Vortrag / Presentation

↑

Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
Veranstaltung	
Memory Device Technology	
Event type	Number
Vorlesung	11LE50V-5726 PO 2021
Organizer	
Institut für Mikrosystemtechnik Sensoren	

ECTS-Points	6.0
Workload	180 Stunden / hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
This course provides an overview on different memory device technologies. The classical memory and storage device types include static random-access memory, dynamic random-access memory, flash, hard disk drive and tape storage. The emerging memory device types include magnetic memory, phase-change memory, resistive random-access memory, ferroelectric memory and electrochemical memory. Along with the basic device concepts, the underlying physics and material properties enabling the memory functionality are explained. The various important performance parameters for memory devices are discussed. New application directions such as in-memory computing and neuromorphic computing hardware are introduced and the requirements for memory devices to be used in such scenarios are discussed.
Examination achievement
Course achievement
Presentation on implemented memory device model and functionality in circuit
Literature
1. Daniele Ielmini, Rainer Waser, "Resistive Switching: From Fundamentals of Nanoionic Redox Processes to Memristive Device Applications", 2016 Wiley-VCH, DOI: 10.1002/9783527680870 2. Jennifer Rupp, Daniele Ielmini, Ilia Valov, "Resistive Switching: Oxide Materials, Mechanisms, Devices and Operations", Springer, DOI: 10.1007/978-3-030-42424-4 3. Andrea Redaelli, Fabio Pellizzer, "Semiconductor Memories and Systems", Elsevier, ISBN 9780128209462
Compulsory requirement
None

Recommended requirement
Basic knowledge on semiconductor physics and semiconductor devices. Having completed the module micro-electronics before taking this module is recommended.

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Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
Veranstaltung	
Memory Device Technology	
Event type	Number
Übung	11LE50Ü-5726 PO 2021

ECTS-Points	
Hours of week	2.0
Recommended semester	2
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercise will recap and deepen on most important aspects of the lecture. In addition, the students will learn how to develop and incorporate emerging memory device models in a compact modeling environment. They will then simulate the behavior of such devices in simple circuits.
Examination achievement
Course achievement
Compulsory requirement

↑

Name of node	Number of node
Materials and Fabrication	11LE50KO-WP-MSc-986-2021 WP2 MaF
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

↑

Name of module	**Number of module**
Bioinspirierte Funktionsmaterialien / Bioinspired functional materials	11LE50MO-5125 PO 2021
Responsible	
Dr. Anayancy Osorio-Madrazo	
Organizer	
Institut für Mikrosystemtechnik Sensoren	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	60
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Bioinspirierte Funktionsmaterialien / Bioinspired functional materials - Vorlesung	Vorlesung		3.0	2.0	90 Stunden

Qualification
In this lecture the students will get fundamental knowledge on the structure and functionality of biological materials as to apply their design principle in the development of bioinspired biomaterials. At the end of the module, the student should be able to describe the interrelation between microstructure and properties in biological materials; apply advance methods for the characterization of microstructure and properties of biological and artificially developed bioinspired materials, and explain the theoretical principle of these methods; and describe the physical-chemistry of the processing of different bioinspired materials studied in the course.
Examination achievement
Part of the Exam "Advanced Macromolcular Materials and Nanostructural Engineering" of the study program M.Sc. Sustainable Materials - Polymer Science. written examination (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	Number of module
Bioinspirierte Funktionsmaterialien / Bioinspired functional materials	11LE50MO-5125 PO 2021
Veranstaltung	
Bioinspirierte Funktionsmaterialien / Bioinspired functional materials - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5125

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Organic-based biological materials. Hierarchical structure and functionality
- Mineralized biological materials. Hierarchical structure and functionality
- Advanced methods to characterize the microstructure and properties of biological and bioinspired materials (Materials physical-chemistry and materials physics: mechanical testing; scattering techniques SAXS and WAXS for microstructure characterization; spectroscopic techniques for chemical structure characterization). Establishment of structure-properties relationship in biomaterials
- Examples of preparation methods of bioinspired materials. Processing physical-chemistry and optimization
- Interrelation between processing, structure and properties in bioinspired materials
- Examples of bioinspired materials for technological and biomedical applications

Examination achievement

see module details

Course achievement

none

Literature

- Materials Design Inspired by Nature. Function through Inner Architecture.
Edited by: P. Fratzl, J. WC Dunlop and R. Weinkamer. RSC Publishing (2013)
- Nature's hierarchical materials
P. Fratzl and R. Weinkamer
Progress in Materials Science , Volume 52, pages 1263-1334, (2007)
- Bioinspiration and biomimetics. Learning from Nature. Edited by: P. Fratzl, T. Speck and S. Gorb. IOP Publishing (2016)
Besides, it will be provided an script accompanying each lecture, which will be updated with recent literature.

Compulsory requirement

none

Recommended requirement
none

↑

Name of module	**Number of module**
Computational physics: material science	11LE50MO-5270 PO 2021
Responsible	
Faculty	
Technische Fakultät	

ECTS-Points	9.0
Workload	270 hours
Recommended semester	
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht

Compulsory requirement
none
Recommended requirement
Basic knowledge in programming (Python, C/C++) as well as statistical mechanics.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Computational Physics: Materials Science	Vorlesung		9.0	4.0	270

Qualification
Application of computational simulation methods can help to discover or design new materials and investigate (microscopic) structure- (macroscopic) property relationships of a wide range of materials classes, such as metals, composites, nanostructures, ice/water, as well as polymers, surfactants, or colloidal dispersions. This course will introduce basic statistical concepts as well as programming and simulations techniques with particular focus on methods based on classical Hamiltonians spanning orders of length and time scales, such as Molecular Dynamics and coarse-grained Langevin Dynamics simulations. The students will become familiar with some examples for the different types of interatomic and coarse-grained potentials: e.g., Lennard-Jones, Born-Mayer, Embedded-Atom, (screened) Coulomb, Hamaker, etc. as well as bonded potentials for molecules and polymers. The course will consist of lectures and hands-on programming exercises and small projects, simulating mostly complex (interacting) fluids and molecules, using own written code.
Examination achievement
The Prüfungsleistung consists of a written exam, and only the result of the written exam contributes to the Prüfungsleistung.
Course achievement
Criteria for passing: For successfully completing the Studienleistung (SL), students must (i) obtain, at least, an average of 50% over all the tutorial sheets , (ii) not miss more than two tutorials (either digital or in presence), and (iii) present their results at least twice during the semester.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Computational physics: material science	11LE50MO-5270 PO 2021
Veranstaltung	
Computational Physics: Materials Science	
Event type	Number
Vorlesung	07LE33V-ADV_THEO_COMP-MAT

ECTS-Points	9.0
Workload	270
Attendance	90
Independent study	180
Hours of week	4.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents

This lecture provides an introduction into basic concepts of atomistic computational materials science. The computational tools for different time and length scales will be introduced and it will be discussed how these tools can be combined in order to solve physical problems extending over too many scales for one single method alone. We will start with a brief introduction to density functional theory and more approximate methods such as tight binding. Quantum derived forces can be extracted from these methods and the short term dynamics of small nanosystems can be studied. For the simulation of larger systems and longer time scales, classical interatomic potentials are required. The students will become familiar with some examples for the different types of interatomic potentials: e.g. Lennard-Jones, Born-Mayer, Embedded-Atom, Bond-Order-potentials as well as bead-spring potentials for polymers. A brief introduction into the basic methodology of micro-canonical and thermostated molecular dynamics simulations will be given.

The lecture is accompanied by a hands-on programming course. Classical molecular dynamics simulations will be used to study metallic and covalently bonded materials.

Examination achievement

Course achievement

Literature

lecture script: A brief Introduction into Computational Materials Science

Compulsory requirement

↑

Name of module	**Number of module**
Disposable sensors	11LE50MO-5259 PO 2021
Responsible	
Organizer	
Institut für Mikrosystemtechnik Sensoren	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine
Recommended requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Disposable sensors	Vorlesung		3.0	2.0	90 Stun-den

Qualification
You understand the basics of different signal detection and amplification strategies. - You know the materials and the fabrication techniques used for disposable sensors. - You learn various biorecognition elements and their working mechanisms. - You overview the recent advances in disposable sensors from different application fields. - You can apply these knowlodge to develop new bioanalytical devices in future.
Examination achievement
written exam with a duration of 90 minutes
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	Number of module
Disposable sensors	11LE50MO-5259 PO 2021
Veranstaltung	
Disposable sensors	
Event type	Number
Vorlesung	11LE50V-5259
Organizer	
Institut für Mikrosystemtechnik Sensoren	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	28 Stunden
Independent study	62 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Disposable sensors are low-cost, single-use and easy-to-handle sensing devices. In recent years, they have become increasingly important for various applications. These include from environmental, forensic, pharmaceutical, agricultural, and food monitoring to wearables and clinical diagnostics, especially the point-of-care testing. This lecture deals with the materials, methods and applications of disposable sensors. 1. Introduction 2. Materials for disposable sensors 3. Biorecognition elements 4. Signal detection techniques 5. Signal amplification strategies 6. Lab-on-a-chip: integration into microfluidic systems 7. Application fields a. Diagnostics b. Food analysis c. Environmental monitoring 8. Future perspectives 9. Summary
Examination achievement
see module details
Course achievement
none
Compulsory requirement
keine

↑

Name of module	**Number of module**
Electrochemical energy applications: fuel cells and electrolysis	11LE50MO-5278 PO 2021
Responsible	
Prof. Dr.-Ing. Roland Zengerle	
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	in jedem Semester

Compulsory requirement
none
Recommended requirement
Knowledge in material science

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Electrochemical energy applications: fuel cells and electrolysis	Vorlesung		3.0	2.0	90 Stun-den

Qualification
understanding/knowledge - basic electrochemistry - hydrogen fuel cell working principle, materials, systems - electrolysis working principle, materials, systems - redox flow batteries - electrochemical and ex-situ characterization methods
Examination achievement
Klausur, Dauer 90 Minuten|written exam, duration 90 minutes
Course achievement
keine

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Electrochemical energy applications: fuel cells and electrolysis	11LE50MO-5278 PO 2021
Veranstaltung	
Electrochemical energy applications: fuel cells and electrolysis	
Event type	Number
Vorlesung	11LE50V-5278
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	in jedem Semester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
none
Recommended requirement
Knowledge in material science

↑

Name of module	Number of module
Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers	11LE50MO-5719 PO 2021
Responsible	
Prof. Dr. Gerald Urban	
Organizer	
Institut für Mikrosystemtechnik Sensoren	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
Recommended requirement
■ Introductory lecture to chemistry or similar knowledge ■ Introductory lecture to electronics or similar knowledge

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers - Vorlesung	Vorlesung		3.0	2.0	90 hours

Qualification
The students know the essential concepts and fundamental equations of electrochemical theory. The participants from different subjects link together the knowledge from physical chemistry and several engineering disciplines to get a sound understanding of the classical electrochemical methods and electrochemical impedance spectroscopy. The students can apply their knowledge and understanding of the electrochemical methods to tasks in the field of material science, microtechnology, microsystems and energy application.
Examination achievement
written examination (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers	11LE50MO-5719 PO 2021
Veranstaltung	
Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5719
Organizer	
Institut für Mikrosystemtechnik Sensoren Institut für Mikrosystemtechnik Elektr. Messt. u. Eingebettete Sys.	

ECTS-Points	3.0
Workload	90 hours
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Electrochemical theory (cells, electrodes, fundamental equation and concepts)
- Instrumentation (focus on the interplay between electrochemistry and electronics/data acquisition), equipment (electrodes, cells), and electrolytes
- Classical methods (potentiometry, amperometry, CV, DPV, SWV, HDME, RDE, RRDE)
- Electrochemical impedance spectroscopy (EIS)
- Selected aspects: Material science (corrosion, hierarchical micro-/nanostructures)
- Selected aspects: Microtechnology (electrodeposition, failure mechanism)
- Selected aspects: Microsystems (electrochemical sensors and actuators)
- Selected aspects: Energy application (fuel cells, batteries, super caps)

Examination achievement

see module details

Course achievement

none

Literature

- Bard, Faulkner: Electrochemical Methods – Fundamentals and Applications, 2nd ed., 2001, Wiley, library: SB/I.1/1
- Hamann, Hamnett, Vielstich: Electrochemistry, 2nd ed., Wiley-VCH 2007, library: SB/H.2/13
- Zoski: Handbook of electrochemistry, 1st ed., Elsevier, 2007, available as ebook (campus license)

Compulsory requirement

Recommended requirement
Introductory lecture to chemistry or similar knowledge Introductory lecture to electronics or similar knowledge

↑

Name of module	**Number of module**
Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells	11LE50MO-5203 PO 2021
Responsible	
Prof. Dr. Claas Müller	
Organizer	
Institut für Mikrosystemtechnik Prozesstechnologie	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells - Vorlesung	Vorlesung		3.0	2.0	90 Stunden

Qualification
Ziel des Moduls ist die Vermittlung der vertieften theoretischen Grundlagen und der spezifischen Kenntnisse zur Speicherung und Wandlung von Energie mittels Brennstoffzellen in mikrotechnischen Systemen.
Examination achievement
Klausur (90 Minuten)
Course achievement
keine
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells	11LE50MO-5203 PO 2021
Veranstaltung	
Energiespeicherung und Wandlung mittels Brennstoffzellen / Energy storage and conversion using fuel cells - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5203
Organizer	
Institut für Mikrosystemtechnik Prozesstechnologie	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Physikalisch chemische Grundlagen Brennstoffzellen
- Aufbau und Funktion von Brennstoffzellen
- Vorstellung unterschiedlicher Brennstoffzellentypen
- Physikalisch chemische Grundlagen der Wasserstoffspeicherung
- Vorstellung von Wasserstoffspeichertypen und -mechanismen
- Diskussion von Vor- und Nachteilen der Wasserstoffspeicher
- Brennstoffzellensysteme im Automobil
- PEM
- DMFC
- Miniaturisierung von Brennstoffzellen
- Mikrobrennstoffzelle
- Chipintegrierte Brennstoffzelle (I^2Brenn)
- Brennstoffzellenakkumulator
- Miniaturisierung der Wasserstofferzeugung
- Einsatz von Brennstoffzellensystemen in der MST

Examination achievement

siehe Modulebene

Course achievement

keine

Literature

Zur Vorlesung wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.

Compulsory requirement

↑

Name of module	Number of module
Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology	11LE50MO-5112 PO 2021
Responsible	
Prof. Dr. Oliver Paul	
Organizer	
Institut für Mikrosystemtechnik Materialien der Mikrosystemtechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none
Recommended requirement
Basic knowledge in microsystems technology and semiconductor physics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology - Vorlesung	Vorlesung		3.0	2.0	90 hours

Qualification
This module provides a more detailed description of silicon technologies exceeding the modules in Microsystemtechnology I and II. The basics in silicon technologies will be accomplished by the most recent results found in literature. Whenever possible, we will organize a visit of the Micronas GmbH in Freiburg and their CMOS Fab.
Examination achievement
Oral examination if there are 20 or fewer than 20 registered participants; written examination if there are more than 20 registered participants (minimum 60 and maximum 240 minutes). Details will be announced by the examiner in due time.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology	11LE50MO-5112 PO 2021
Veranstaltung	
Fortgeschrittene Siliziumtechnologie / Advanced Silicon Technology - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5112
Organizer	
Institut für Mikrosystemtechnik Materialien der Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Substrate materials, oxidation, diffusion, implantation, polysilicon and epitaxy, silisides, metallisation, dielectric layers, SiGe, strained silicon, low- und high-k-dielectrics, photo lithography (immersion lithography, phase shift mask, EUV, chemical-mechanical polishing, process integration, CMOS-compatible micro mechanics
Examination achievement
see module details
Course achievement
none
Literature
▪ Chang/Sze: ULSI Technology, Wiley ▪ Semiconductor International: monatliche Technologie-Zeitschrift
Compulsory requirement
Recommended requirement
Basic knowledge in microsystems technology and semiconductor physics

↑

Name of module	**Number of module**
Functional Safety, Security and Sustainability: Active Resilience	11LE68MO-5120 PO 2021
Responsible	
Prof. Dr. Anke Weidlich	
Organizer	
Inst. f. Nachh. Technische Systeme Nachhaltige Ingenieursysteme	
Faculty	
Technische Fakultät Institut für Nachhaltige Technische Systeme	

ECTS-Points	3.0
Workload	90 h
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement

None

Recommended requirement

Any basics in any of the following areas would be helpful but are not mandatory:

- system description and modelling
- graphical/ semiformal modelling
- product and development life cycles
- classical system analysis
- reliability analysis for any engineering discipline, e.g. electronics, computer science, mechanical, civil and aerospace engineering
- Machine Learning/Artificial Intelligence (ML/AI) methods

Assigned Courses

Name	Type	P/WP	ECTS	HoW	Workload
Functional Safety, Security and Sustainability: Active Resilience - Vorlesung	Vorlesung		3.0	2.0	90 h

Qualification

Main learning targets include:
1. Know main (emerging) application domains, e.g. digitalized production, autonomous transport, aerospace, safety of self-learning systems, and renewable energy systems
2. Knowledge how to achieve acceptable overall safety (risk control), security, sustainability, and resilience of socio-technical (safety relevant and critical) systems through reliable functions
3. Knowledge and tailoring of definitions, types and effects of reliability functions
4. Relation of functional safety to related concepts for security and sustainability generation
5. Knowledge and tailoring of safety life cycle, development processes and process steps to plan, develop, verify and validate reliability or safety functions

6. Knowledge, tailoring, process-driven application, quantification and evaluation, executive conclusions development, and litigable documentation of mainly quantitative system analysis methods
7. Knowledge of required development methods and how to combine and tailor them for achieving functional safety
8. Know failure types and how to avoid and control them with techniques and measures for hardware and software
9. Knowledge and application of assessment quantities for reliable functions, e.g. safety integrity level (on demand or continuous), hardware failure tolerance, diagnostic coverage, safe failure fraction, complexity level
10. Understanding of the role of Machine Learning (ML) and artificial intelligence (AI) approaches as part of considered systems or of the functional safety process and methods, and related emerging options
11. Knowledge of reliability prediction methods and related standards
12. Applicable knowledge of related standardization landscape

Examination achievement

Written supervised examination at the end of the semester covering the content of the lecture and its embedded exercises contributing 100% to the final grade. Duration: 90 minutes.

Important info for exchange students: the exam must be taken at the official examination date.

Course achievement

Presentation and critical review of selected publications or of chapter of the lecture manuscript (approx. 20 minutes including questions and answers).

Usability

Elective module for students of the study program
- M.Sc. in Sustainable Systems Engineering (PO 2021) in the technical concentration area *Resilience Engineering*
- M.Sc. in Microsystems Engineering (PO 2021), Concentration Materials and Fabrication
- M.Sc. in Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse
- M.Sc. in Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	Number of module
Functional Safety, Security and Sustainability: Active Resilience	11LE68MO-5120 PO 2021
Veranstaltung	
Functional Safety, Security and Sustainability: Active Resilience - Vorlesung	
Event type	Number
Vorlesung	11LE68V-5120 PO 2021
Organizer	
Institut für Nachhaltige Technische Systeme	

ECTS-Points	3.0
Workload	90 h
Attendance	26 h
Independent study	64 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Main content: 1. Definition of functional safety, safety functions, safety integrity level (SIL), safety related systems and related key quantities, e.g. hardware failure tolerance (HFT), complexity, diagnostic coverage (DC), safe failure fraction (SFF) 2. Relation and transfer of functional safety to reliability, availability, security, IT-security, sustainability, and resilience 3. Functional safety, security, sustainability and resilience life cycle models (management and development processes): general and phase-specific requirements 4. System definition and graphical/semi-formal modelling for system analysis, e.g. with UML and SysML 5. Inductive analytical tabular system analysis methods: e.g. hazard analyses (PHL, PHA, SSH, O and SHA, HAZOP), hazard log, failure mode and effects analysis (FMEA, FMEDCA), double failure matrix 6. (Deductive) Graphical system analysis methods: Fishbone diagram, Event Tree Analysis, Reliability block diagram (RBDs), Fault tree analysis (FTA, TDFTA) 7. Markov models and Petri nets 8. (Semi) Quantification and evaluation of system analysis methods, e.g. using risk priority numbers, parts count and parts stress, reliability prediction standards, Boolean algebra and importance measures for FTA, quantitative measures for graph-based methods, computation and simulation approaches for Markov and Petri models 9. Overview on methods for requirements determination, e.g. SIL: graphical, numerical, analytical, statistical, simulation based using individual and collective risk criteria 10. Safety and reliability function architecture allocation, e.g. MooN, MooND 11. Overview on techniques and measures for hardware and software to avoid and control systematic errors of hardware and software and to avoid and control statistic errors of hardware 12. Combination and tailoring of processes and methods 13. Application domains and examples: e.g. automation, production, automotive, transport, energy generation, systems with ML/AI, e.g. autonomous driving 14. Use of ML/AI for safety assessment and development 15. Standardization landscape, e.g. functional safety standards IEC 61508, ISO 26262 and safety of intended functionality ISO/PAS 21448

16. Emerging standards, future risk control and resilience generation challenges, e.g. AI and superintelligence control

Qualification

Examination achievement

See module

Course achievement

See module

Literature

Sample literature:

1. Satisfying safety goals by probabilistic risk analysis, Hiromitsu Kumamoto, Springer 2007
2. Modern statistical and mathematical methods in reliability, Alyson Wilson et. al. (eds.), World Scientific, 2005
3. Mathematical and statistical methods in reliability, Bo H Lindqvist and Kyell A Doksum, World Scientific, 2003
4. Hazard analysis techniques for system safety, Clifton A. Ericson, Wiley, 2015
5. FRAM: the functional resonance analysis method, Erik Hollnagel, Ashgate, 2012
6. Synesis: The Unification of Productivity, Quality, Safety and Reliability, Erik Hollnagel, Ashgate, 2020
7. Control systems safety evaluation and reliability, William M. Gobe, 2010
8. System reliability theory: models, statistical methods and applications, Marvin Rausand, Arnljot Hoyland, Wiley-Interscience, 2004
9. Risk assessment: theory, methods, and application, Marvin Rausand, Wiley, 2011
10. Reliability of safety-critical systems: theory and applications, Marvin Rausand, Wiley, 2014
11. Risk and resilience: methods and application in environment, cyber and social domains, Eds.: Igor Linkov, Jose Manuel Palma-Oliviera, Springer, 2017
12. Functional safety for road vehicles: new challenges and solutions for e-mobility and automated driving, Hans-Leo Ross, Springer, 2016
13. Functional Safety of Machinery: Sample Questions and Solutions, Jagadeesh-Pandiyan, author's edition, 2019
14. Functional safety in practice, Harvey T Dearden, CreateSpace Independent Publishing Platform, 2018
15. Modeling for reliability analysis: Markov modeling for reliability, maintainability, safety, and supportability analyses of complex systems, Jan van Pukite, Paul Pukite, Wiley-IEEE Press, 1998
16. Applied reliability engineering and risk analysis: probabilistic models and statistical inference, Editor(s): Ilia B. Frenkel, Alex Karagrigoriou, Anatoly Lisnianski, Andre Kleyner, John Wiley & Sons, 2013
17. Reliability engineering: theory and practice, Alessandro Birolini, Springer, 2013
18. Electronic safety systems: hardware concepts, models, calculations, Josef Börcsök, Hüthig, 2004
19. Functional Safety: Basic Principles of Safety-related Systems, Josef Börcsök, Hüthig, 2020
20. Zuverlässigkeitstechnik, Arno Meyna and Bernhard Pauli, Hanser, 2010
21. The safety critical systems handbook, David J. Smith, Butterworth-Heinemann, 2010
22. Reliability and availability engineering: modeling, analysis, and applications, Kishor S. Trivedi, Andrea Bobbio, Cambridge University Press, 2017
23. Embedded Software Development for Safety-Critical Systems, Chris Hobbs, CRC Press, 2019
24. Dynamic Probabilistic Systems, Volume I: Markov Models, Ronand A. Howard, Dover publications, 2012
25. Dynamic Probabilistic Systems, Volume II: Semi-Markov and Decision Processes, Ronand A. Howard, Dover publications, 2013
26. Fault-Tolerant Systems, Israel Koren, C. Mani Krishna, Morgan Kaufmann Publisher, 2020
27. Semi-Markov Processes: Applications in System Reliability and Maintenance, Franciszek Grabski, Elesevier, 2014

28. Risk analysis and management: engineering resilience, Ivo Häring, Springer 2015
29. A Primer in Petri Net Design, Wolfgang Reisig, Springer, 1992
30. Ereignisdiskrete Systeme: Modellierung und Analyse dynamischer Systeme mit Automaten, Markovketten und Petrinetzen, Jan Lunze, De Gruyter, 2017
31. System Modeling and Control with Resource-Oriented Petri Nets, MengChu Zhou, Routledge, 2017
32. Formal Methods in Computer Science, Jiacun Wang, William Tepfenhart, Taylor & Francis, 2019
33. Technical Safety, Reliability and Resilience: Methods and Processes, I. Häring, Springer, 2021
34. From event to performance function-based resilience analysis and improvement processes for more sustainable systems, I. Häring, J. Schäfer, et al., International Journal of Sustainable Materials and Structural Systems, 5(1/2), 2021, pp.90 - 120
35. Functional safety assessment of distributed predictive heating and cooling systems for electric delivery vehicles, Y. Satsrisakul, I. Häring, et al., ESREL 2021

Further information:
Sample related standards for information
- https://www.iec.ch/functionalsafety/
- https://www.iso.org/standard/68383.html
- https://www.iso.org/standard/70939.html

Recent publications: https://scholar.google.com/citations?user=luyHvrkAAAAJ&hl=en

Compulsory requirement
None
Recommended requirement
Any basics in any of the following areas would be helpful but are not mandatory: ■ system description and modelling ■ graphical/ semiformal modelling ■ product and development life cycles ■ classical system analysis ■ reliability analysis for any engineering discipline, e.g. electronics, computer science, mechanical, civil and aerospace engineering
Teaching method
Lecture with integrated exercises.

↑

Name of module	**Number of module**
Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Method	11LE50MO-5503 PO 2021

Responsible
Prof. Dr. Jürgen Wilde
Organizer
Institut für Mikrosystemtechnik Aufbau- u. Verbindungstechnik
Faculty
Technische Fakultät Institut für Mikrosystemtechnik

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine
Recommended requirement
Kenntnisse in Assembly and Packaging Technology oder Aufbau- und Verbindungstechnik

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Method - Praktische Übung	Praktikum		6.0	4.0	180 Stunden

Qualification
It is the aim, that after this module, the student will know the fundamental physical problems in electronic hardware based on own numerical investigations. The student will have elementary capabilities to solve praxis-relevant design problems in assembly and packaging of MEMS using a professional finite-element-system. He/she will know how experiments can be replaced by simulation and what the necessary input data are. He/she will be able to work with the Finite-Element-Code and to modify complex existing models. Furthermore it is expected that the student will have improved capabilities in the analysis of industrial problems and on reporting of the corresponding results.

Examination achievement
Benotete Protokolle und eine schriftliche Prüfung auf der Grundlage der Protokolle. Bei geringer Teilnehmerzahl kann anstelle der schriftlichen Prüfung eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig darüber informiert. Graded protocols and a written examination based on the protocols. If the number of participants is very small, an oral examination may be held instead of the written exam. The students will be informed in good time.
Course achievement
keine / none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Method	11LE50MO-5503 PO 2021
Veranstaltung	
Hardware-Entwicklung mit der Finite-Elemente-Methode / Hardware Design with the Finite-Element-Method - Praktische Übung	
Event type	Number
Praktikum	11LE50P-5503

ECTS-Points	6.0
Workload	180 Stunden
Attendance	60
Independent study	120
Hours of week	4.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement
none
Recommended requirement
Knowledge in Assembly and Packaging Technology or Aufbau- und Verbindungstechnik

↑

Name of module	**Number of module**
High-Performance Computing: Fluid Mechanics with Python	11LE50MO-5285 ESE PO 2021
Responsible	
Prof. Dr. Lars Pastewka	
Organizer	
Institut für Mikrosystemtechnik Simulation	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden | hours
Recommended semester	2
Duration	1 semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
High-Performance Computing: Fluid Mechanics with Python	Vorlesung		6.0	2.0	180 Stunden
High-Performance Computing: Fluid Mechanics with Python	Übung			2.0	

Qualification

The student
- can use Python for solving numerical problems using the numpy and scipy libraries and knows strategies for writing efficient code
- can apply the Message Passing Interface (MPI) libraries to parallelize specific numerical problems
- can use job submission systems on parallel computers to run their Python codes.

Examination achievement

Written examination. The students have to submit a written report, describing numerical results and scaling tests obtained with their simulation code.

Course achievement

none

Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Mikrosystemtechnik As compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering and M.Sc. Mikrosystemtechnik ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Materials and Fabrication Students enrolled in the Master of Science in Sustainable Systems Engineering (2021 version of the exam- regulations) can complete this elective module in the technical concentration area *Sustainable Materials Engineering* or *Interdisciplinary Profile - Modules <u>related to</u> the Subject Area.*

↑

Name of module	Number of module
High-Performance Computing: Fluid Mechanics with Python	11LE50MO-5285 ESE PO 2021
Veranstaltung	
High-Performance Computing: Fluid Mechanics with Python	
Event type	Number
Vorlesung	11LE50V-5285
Organizer	
Institut für Mikrosystemtechnik Simulation	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

This class teaches parallel scientific computing with Python using the numpy library for fast array operations. Parallelization strategies that use the Message Passing Interface (MPI) will be presented. These technical concepts will be applied to the solution of fluid mechanical problems using the lattice Boltzmann method.

Scientific computing:
1. Efficient Python: basics, numpy arrays, numpy operations, scipy
2. Translating mathematical expressions into efficient array operations
3. The Message Passing Interface (MPI)
4. Parallelization strategies
5. Practical aspects of working with High-Performance clusters

Fluid mechanics and the Lattice Boltzmann method:
6. Phenomenology of fluid mechanics
7. Lattice gas and lattice Boltzmann
8. Boundary conditions

Examination achievement

See module level

Course achievement

See module level

Literature

A. Scopatz, K.D. Huff, "Effective Computation in Physics" (O'Reilly 2015)
W.A. Wolf-Gladrow, "Lattice-Gas Cellular Automata and Lattice Boltzmann Models" (Springer 2000)

T. Krüger, H. Kusumaatmaja, A. Kuzmin, O. Shardt, G. Silva, E.M. Viggen, "The Lattice Boltzmann Method" (Springer 2017)
Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

↑

Name of module	Number of module
High-Performance Computing: Fluid Mechanics with Python	11LE50MO-5285 ESE PO 2021
Veranstaltung	
High-Performance Computing: Fluid Mechanics with Python	
Event type	Number
Übung	11LE50Ü-5285
Organizer	
Institut für Mikrosystemtechnik Simulation	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The students will implement their own parallel Lattice Boltzmann simulation code in the computer lab accompanying this lecture series.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

↑

Name of module	**Number of module**
High-Performance Computing: Molecular Dynamics with C++	11LE50MO-5288 PO 2021
Responsible	
Prof. Dr. Lars Pastewka	
Organizer	
Institut für Mikrosystemtechnik Simulation	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden | hours
Recommended semester	2
Duration	1 semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
High-Performance Computing: Molecular Dynamics with C++	Vorlesung		6.0	2.0	180 hours
High-Performance Computing: Molecular Dynamics with C++	Übung			2.0	-

Qualification

The student
- understands the physics of interatomic bonds, potential energy landscapes and the statistical foundations of thermodynamics
- can transfer these concepts to molecular simulations, in particular interatomic potentials, transition paths, thermostats and barostats
- can select initial conditions and interatomic potentials, run a molecular dynamics simulation and evaluate and interpret the simulation results

Examination achievement

Written report

Course achievement
There are exercises at regular intervals that have to be worked on and handed in.These are corrected and assessed with points. The course work is passed if 50% of the excercise sheets have been successfully completed.

Usability
As compulsory elective in ■ M.Sc. Microsystems Engineering (PO 2021), Concentrations Area: Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Informatik / Computer Science in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Materials and Fabrication ■ Students enrolled in the Master of Science in Sustainable Systems Engineering (2021 version of the exam regulations) can complete this elective module in the technical concentration area *Sustainable Materials Engineering.*

↑

Name of module	**Number of module**
High-Performance Computing: Molecular Dynamics with C++	11LE50MO-5288 PO 2021
Veranstaltung	
High-Performance Computing: Molecular Dynamics with C++	
Event type	Number
Vorlesung	11LE50V-5286
Organizer	
Institut für Mikrosystemtechnik Simulation	

ECTS-Points	6.0
Workload	180 hours
Attendance	56 Stunden
Independent study	124 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
This lecture introduces atomic-scale simulation techniques with a focus on solid mechanics. 1. Materials physics 2. Interatomic potentials 3. Molecular statics and potential energy landscapes 4. Molecular dynamics 5. Classical statistical mechanics 6. Thermostats and barostats 7. Analysis and visualization
Examination achievement
see module details
Course achievement
see module details
Literature
Understanding Molecular Simulation: From Algorithms to Applications, Daan Frenkel and Berend Smit (Academic Press, 2001) Computer simulation of liquids, M. P. Allen and Dominic J. Tildesley (Clarendon Press, Oxford, 1996)
Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

↑

Name of module	**Number of module**
High-Performance Computing: Molecular Dynamics with C++	11LE50MO-5288 PO 2021
Veranstaltung	
High-Performance Computing: Molecular Dynamics with C++	
Event type	Number
Übung	11LE50Ü-5286
Organizer	
Institut für Mikrosystemtechnik Simulation	

ECTS-Points	
Workload	-
Attendance	-
Independent study	-
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The students will solve problems from materials science with a widely used molecular simulation code. Successful completion of >=50% of exercise sheets
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Knowledge of a programming language (not necessarily Python, i.e. Java, C, C++, etc.)

↑

Name of module	Number of module
High-Performance Computing: Molecular Dynamics with C++	11LE50MO-5288 PO 2021
Name of Examination	
Exam type	Number
Responsible	
Faculty	

Exam form	
Grading	
Recommended semester	4
Compulsory	

↑

Name of module	Number of module
Introduction to (Bioinspired) Programmable Meta Materials	11LE50MO-5287 PO 2021
Responsible	
Prof. Dr. Christoph Eberl	
Organizer	
Institut für Mikrosystemtechnik Mikro- und Werkstoffmechanik	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden / hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
Keine / none
Recommended requirement
Bachelor in engineering or natural sciences and related studies.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Introduction to (Bioinspired) Programmable Meta Materials	Vorlesung		6.0	2.0	180 Stunden / hours
Introduction to (Bioinspired) Programmable Meta Materials	Übung			2.0	

Qualification
Concluding this course enables you to design programmable mechanical metamaterials. You will know how to prototype such materials and be able to characterize their behavior. You will be able to relate algorithms from biological model systems which can be implemented into programmable materials. You will understand the mechanics behind it.
Examination achievement
Prüfungsgespräch / oral examination
Course achievement
Referat, Vortrag / presentation There will be lab courses where characterization methods will be introduced. Students will design, simulate or manufacture programmable metamaterials and present their project at the end.

↑

Name of module	Number of module
Introduction to (Bioinspired) Programmable Meta Materials	11LE50MO-5287 PO 2021
Veranstaltung	
Introduction to (Bioinspired) Programmable Meta Materials	
Event type	Number
Vorlesung	11LE50V-5287 PO 2021
Organizer	
Institut für Mikrosystemtechnik Mikro- und Werkstoffmechanik	

ECTS-Points	6.0
Workload	180 Stunden / hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
1. Programmable Materials: from properties to abilities (should we combine the first two?) 2. The introduction of mechanical metamaterials and their manufacturing and possible applications 3. Learning from nature – plant mechanics and function integration in biological role models 4. Semantic description of materials 5. Calculating analytical relationships for the mechanical properties of 2D and 3D metamaterials 6. Simulation of the mechanical metamaterials unit cells and lattices under periodic boundary condition. 7. Introducing nonlinearities and instabilities such as buckling and bistability in metamaterials (Mechanisms, Simulations and experimental examples) 8. Structural and mechanical characterization: how to measure complex structurers as well as nonlinear and discontinuous behavior 9. How to introduce algorithms into programmable mechanical meta materials (Simulation and Experiments) 10. Programming mechanical metamaterials for specific functionalities 11. An introduction to forward and inverse design with machine learning 12. Manufacturing of (programmable) meta materials and the semantic description of manufacturing 13. Wrap-up
Examination achievement
Course achievement
Compulsory requirement
Keine / none
Recommended requirement
Bachelor in engineering or natural sciences and related studies.

↑

Name of module	**Number of module**
Introduction to (Bioinspired) Programmable Meta Materials	11LE50MO-5287 PO 2021
Veranstaltung	
Introduction to (Bioinspired) Programmable Meta Materials	
Event type	Number
Übung	11LE50Ü-5287 PO 2021
Organizer	
Institut für Mikrosystemtechnik Mikro- und Werkstoffmechanik	

ECTS-Points	
Hours of week	2.0
Recommended semester	2
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Students learn the application of the courses content in the excercises. Students will design, simulate or manufacture programmable metamaterials and present their project at the end.
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for microsystems	11LE50MO-5102 PO 2021
Responsible	
Prof. Dr. Thomas Hanemann	
Organizer	
Institut für Mikrosystemtechnik Werkstoffprozesstechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine
Recommended requirement
Kenntnisse der Werkstoffwissenschaft, z.B. Zustandsdiagramme, physikalische Eigenschaften verschiedener Materialklassen, Kristallsysteme, thermodynamische Eigenschaften und Kinetik kristalliner und nichtkristalliner Festkörper

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for microsystems - Vorlesung	Vorlesung		3.0	2.0	90 Stunden

Qualification
Ziel des Moduls ist es, die technologischen und physikalischen Grundlagen der keramischen Werkstoffe und die zugehörigen Prozessierungsmethoden zu vermitteln. Mikrosystemtechnisch relevante Aspekte der keramischen Werkstoffe und ihrer Prozessierungsmethoden sollen aufgezeigt werden.
Examination achievement
Schriftliche Prüfungsleistung von 90 Minuten Dauer Wenn die Teilnehmerzahl gering ist, kann stattdessen eine mündliche Prüfung (30 Minuten) durchgeführt werden. Die Studierenden werden rechtzeitig informiert.

Course achievement
keine
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	Number of module
Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for microsystems	11LE50MO-5102 PO 2021
Veranstaltung	
Keramische Werkstoffe der Mikrotechnik / Ceramic Materials for microsystems - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5102
Organizer	
Institut für Mikrosystemtechnik Werkstoffprozesstechnik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Im ersten Teil werden die allgemeinen Aspekte keramischer Werkstoffe mit den Schwerpunkten Oxid- und Nichtoxidkeramiken sowie Magnetkeramiken behandelt. Weitere Kapitel betreffen die Herstellung keramischer Pulver, die Charakterisierung von Pulvern und Keramiken und die Herstellung und Beschreibung von Pulversuspensionen. Anschließend wird die Herstellung keramischer Komponenten für die Mikrotechnik nach unterschiedlichen Verfahren (Trockenpressen, Schlickergießen, elektrophoretische Abscheidung, Foliengießen, pulverkeramisches Spritzgießen) vorgestellt. Die Vorlesung schließt mit einer Einführung in Sinterprozesse. Es besteht die Möglichkeit, im Anschluss an die Vorlesung ein ca. 2-wöchiges Blockpraktikum zu absolvieren. Dieses dient dazu die in der Vorlesung theoretisch behandelten Themen praktisch umzusetzen.
Examination achievement
siehe Modulebene
Course achievement
keine
Literature
Begleitend zur Vorlesung wird ein Skriptum und werden Handzettel der Vorlesungsfolien zur Verfügung gestellt.
Compulsory requirement
keine
Recommended requirement
Kenntnisse der Werkstoffwissenschaft, z.B. Zustandsdiagramme, physikalische Eigenschaften verschiedener Materialklassen, Kristallsysteme, thermodynamische Eigenschaften und Kinetik kristalliner und nichtkristalliner Festkörper

↑

Name of module	**Number of module**
Kontinuumsmechanik I mit Übungen / Continuum mechanics I with exercises	11LE50MO-4302 PO 2021
Responsible	
Dirk Helm	
Organizer	
Inst. f. Nachh. Technische Systeme Nachhaltige Ingenieursysteme	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 h
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
Advanced mathematics; engineering mechanics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Kontinuumsmechanik I - Vorlesung	Vorlesung		6.0	2.0	180 h
Kontinuumsmechanik I / Continuum Mechanics I	Übung			2.0	

Qualification
The objective of the module is to master the mathematical foundations of continuum mechanics in form of tensor algebra and tensor analysis as well as the knowledge of the basic structure of continuum mechanics. The content of the topics of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.
Examination achievement
Oral examination (one-on-one, Prüfungsgespräch) with a max. duration of 45 min. The oral examination covers the content of the lecture and exercises. Important info for exchange students: the examination must be taken at the official examination date!

Course achievement
none
Usability

Elective Module for students of the study program
■ Master of Science in Sustainable Systems Engineering (2021 version of the exam regulations):
  ■ Resilience Engineering
  ■ Sustainable Materials Engineering
■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication
■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse
■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	**Number of module**
Kontinuumsmechanik I mit Übungen / Continuum mechanics I with exercises	11LE50MO-4302 PO 2021
Veranstaltung	
Kontinuumsmechanik I - Vorlesung	
Event type	Number
Vorlesung	11LE68V-4301
Organizer	
Institut für Nachhaltige Technische Systeme	

ECTS-Points	6.0
Workload	180 h
Attendance	52 h
Independent study	128 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Mathematical foundations of continuum mechanics (specialized to orthonormal base systems) consisting of tensor algebra and tensor analysis
- Introduction to the basic structure of continuum mechanics (kinematics, balance equations, constitutive relations).
- The focus lies on the treatment of small deformations and simplified examples with reference to engineering mechanics.

Examination achievement

See module

Course achievement

See module

Literature

- M. Itskov, Tensor Algebra and Tensor Analysis for Engineers, Springer, 2013

Compulsory requirement

None

Recommended requirement

Advanced mathematics; engineering mechanics

Teaching method

Lecture + exercise

↑

Name of module	**Number of module**
Kontinuumsmechanik I mit Übungen / Continuum mechanics I with exercises	11LE50MO-4302 PO 2021
Veranstaltung	
Kontinuumsmechanik I / Continuum Mechanics I	
Event type	Number
Übung	11LE68Ü-4302
Organizer	
Institut für Nachhaltige Technische Systeme	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The content of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.
Examination achievement
See module
Course achievement
See module
Literature
See lecture
Compulsory requirement
None
Recommended requirement
See lecture

↑

Name of module	**Number of module**
Kontinuumsmechanik II mit Übungen / Continuum mechanics II with exercises	11LE50MO-4304 PO 2021
Responsible	
Dirk Helm	
Organizer	
Inst. f. Nachh. Technische Systeme Nachhaltige Ingenieursysteme	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 h
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
■ Module Continuum Mechanics I with Exercises

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Kontinuumsmechanik II - Vorlesung	Vorlesung		6.0	2.0	180 h
Kontinuumsmechanik II / Continuum Mechanics II	Übung			2.0	See lecture

Qualification
The objective of the course is the knowledge of nonlinear continuum mechanics and its applications in solid state and fluid mechanics. The content of the topics of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.
Examination achievement
Oral examination (one-on-one, Prüfungsgespräch) with a max. duration of 45 min. The oral examination covers the content of the lecture and exercises. Important info for exchange students: the examination must be taken at the official examination date.
Course achievement
none

Usability

Elective Module for students of the study program
 	
- Master of Science in Sustainable Systems Engineering (2021 version of the exam regulations):
  - Resilience Engineering
  - Sustainable Materials Engineering
- M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication
- M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse
- M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	Number of module
Kontinuumsmechanik II mit Übungen / Continuum mechanics II with exercises	11LE50MO-4304 PO 2021
Veranstaltung	
Kontinuumsmechanik II - Vorlesung	
Event type	Number
Vorlesung	11LE68V-4303
Organizer	
Institut für Nachhaltige Technische Systeme	

ECTS-Points	6.0
Workload	180 h
Attendance	60 h
Independent study	120 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Kinematics for finite deformations: representation of motion, strain tensors etc. at large deformations, geometric linearization
- Balance relations of mechanics and thermomechanics
- Principles of mechanics: principle of D'Alembert, principle of virtual displacements
- Constitutive relations for fluids and solids (e.g. linear-elastic fluid, finite elasticity, viscoelasticity, plasticity, viscoplasticity, heat conduction, ...)
- Extension of the mathematical foundations of tensor algebra and tensor analysis to general base systems and curved coordinates

Examination achievement

See module

Course achievement

See module

Literature

- P. Haupt, Continuum Mechanics and Theory of Materials, Springer Verlag, 2002

Compulsory requirement

None

Recommended requirement

Module *Continuum Mechanics I with Exercises*

Teaching method

Lecture + exercise

↑

Name of module	**Number of module**
Kontinuumsmechanik II mit Übungen / Continuum mechanics II with exercises	11LE50MO-4304 PO 2021
Veranstaltung	
Kontinuumsmechanik II / Continuum Mechanics II	
Event type	Number
Übung	11LE68Ü-4304
Organizer	
Institut für Nachhaltige Technische Systeme	

ECTS-Points	
Workload	See lecture
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The content of the lecture will be further studied by exercises in order to train the mathematical foundations and the first applications in the field of continuum mechanics.
Examination achievement
See module
Course achievement
See module
Literature
See lecture
Compulsory requirement
See lecture
Recommended requirement
See lecture
Teaching method
See lecture

↑

Name of module	**Number of module**
Konstitutive Gleichungen und Diskretisierungsverfahren zur Versagensmodellierung / Physics of Failure	11LE50MO-5121 PO 2021
Responsible	
Prof. Dr. Stefan Hiermaier	
Organizer	
Inst. f. Nachh. Technische Systeme Nachhaltige Ingenieursysteme	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 h
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Konstitutive Gleichungen und Diskretisierungsverfahren zur Versagensmodellierung - Vorlesung	Vorlesung		3.0	2.0	90 h

Qualification
With this module students are able to distinguish between damage and failure as two distinct process types in materials as other thermo-mechanic behaviors. Basic differences between phenomenological and physics based modeling approaches become evident. Specifically, the multi-scale character of the process is recognized. The resulting dimension of related resources for computations as well as the necessity for scale-bridging methodologies is learnt. Furthermore, a variety of experimental and numerical methods for characterizing and modeling the processes is investigated.
Examination achievement
Oral examination (Prüfungsgespräch), duration: approx. 20 min. per student. The oral exam covers the content of the lecture.
Course achievement
none

Usability

Elective Module for students of the study program
 	
■ Master of Science in Sustainable Systems Engineering (2021 version of the exam regulations):
  ■ Resilience Engineering
  ■ Sustainable Materials Engineering
■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication
■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse
■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	Number of module
Konstitutive Gleichungen und Diskretisierungsverfahren zur Versagensmodellierung / Physics of Failure	11LE50MO-5121 PO 2021
Veranstaltung	
Konstitutive Gleichungen und Diskretisierungsverfahren zur Versagensmodellierung - Vorlesung	
Event type	Number
Vorlesung	11LE68V-5121
Organizer	
Inst. f. Nachh. Technische Systeme Nachhaltige Ingenieursysteme	

ECTS-Points	3.0
Workload	90 h
Attendance	30 h
Independent study	60 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Fracture mechanics ■ crack propagation and opening modes ■ energy release rate ■ crack tip stress state (stress intensity factors, J integral) ■ cohesive zone model Failure of materials ■ failure criteria models (Tresca, Hill…) ■ failure surfaces ■ stress triaxiality (e.g. Johnson-Cook) Damage mechanics ■ strength degradation ■ damage accumulation models The theoretical, experimental, numerical and empirical approaches to the topics are accompanied with many examples from science and industry.
Examination achievement
See module
Course achievement
See module
Literature
Information will be given during the lecture.

Compulsory requirement
None
Recommended requirement
None
Teaching method
Lecture

↑

Name of module	Number of module
Lithographie / Lithography	11LE50MO-5603 PO 2021
Responsible	
Prof. Dr. Claas Müller	
Organizer	
Institut für Mikrosystemtechnik Prozesstechnologie	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Lithographie / Lithography - Vorlesung	Vorlesung		3.0	2.0	90 Stunden

Qualification
Ziel des Moduls ist die Vermittlung der Kenntnisse, die für ein ganzheitliches Verständnis der lithographischen Verfahren, die in der Mikrosystemtechnik eingesetzt werden.
Examination achievement
mündliche Abschlussprüfung (20-30 Minuten)
Course achievement
keine
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	**Number of module**
Lithographie / Lithography	11LE50MO-5603 PO 2021
Veranstaltung	
Lithographie / Lithography - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5603
Organizer	
Institut für Mikrosystemtechnik Prozesstechnologie	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Optische Mikroskopie
- Hellfeld Beleuchtung
- Dunkelfeld Beleuchtung
- Aperturblende
- Geschichtsfeldblende
- Aufbau und Funktion von Photoresisten
- Positiv und negativ Resiste
- Chemischer Aufbau der Resiste
- Lithographische Masken
- Herstellung
- Materialien
- Aufbau
- Grenzen
- Aufbau und Funktion von Maskaligner
- Justage Vorderseite und Rückseite
- Belichtungsmodi
- Prozessablauf und Prozessketten
- Charakterisierung von lithographisch hergestellten Strukturen
- Weiterführende Prozessvarianten

Examination achievement

siehe Modulebene

Course achievement

keine

Literature

Begleitend zur Vorlesung wird ein Skriptum zur Verfügung gestellt und regelmäßig aktualisiert.

Compulsory requirement
keine

↑

Name of module	**Number of module**
Machine Learning Approaches in Structural Mechanics	11LE50MO-5722 PO 2021
Responsible	
Prof. Dr. Lars Pastewka Dr. Viacheslav Slesarenko	
Organizer	
Institut für Mikrosystemtechnik Simulation	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Machine Learning Approaches in Structural Mechanics	Vorlesung		6.0	2.0	
Machine Learning Approaches in Structural Mechanics	Übung			2.0	

Qualification
After the completion of the module, students will be able to: 1. Understand different neural network topologies and their possible applications in mechanical engineering and structural mechanics; 2. Understand the interplay between optimization and machine learning; 3. Analyze and augment datasets obtained via experiments or simulations; 4. Program simple architectures and make predictions on the mechanical behavior of materials and structu-res; 5. Understand the limitations of proposed approaches and the ways to overcome them using state-of-art publications.
Examination achievement
Prüfungsgespräch / oral examination (idR 30-45 Minuten/usually 30 or 45 minutes)

Course achievement
Protokoll / written lab report: ■ Each student has to solve one practical problem using appropriate studied machine learning techniques, analyze obtained results, and provide a written report accompanying the code. Sample problems will be provided, however, students are encouraged to explore other problems from mechanical engineering after prior approval by the lecturer. Among provided problems are: predicting the properties in mechanical lattices, detecting the crack; obtaining the critical load of the heterogeneous column.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Machine Learning Approaches in Structural Mechanics	11LE50MO-5722 PO 2021
Veranstaltung	
Machine Learning Approaches in Structural Mechanics	
Event type	Number
Vorlesung	11LE50V-5722 PO 2021
Organizer	
Institut für Mikrosystemtechnik Simulation	

ECTS-Points	6.0
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
This course is designed mainly for students with an engineering background who want to understand machine learning and get hands-on experience in programming artificial neural networks. Using examples from mechanical engineering (primarily structural mechanics), students will learn the main ML approaches (NN, SVM, anomaly detection, DL, etc.). They will understand how to implement corresponding ML architectures in popular frameworks, such as TensorFlow and scikit-learn. Students will learn how to obtain initial datasets, process them, choose the best-suited approaches and what to do with obtained results. The classical forward (structure - properties) and inverse (properties - structure) problems will be discussed.
Examination achievement
see module details
Course achievement
see module details
Literature
Ryan G. McClarren, Machine Learning for Engineers. Springer, 2021 Andriy Burkov, The Hundred-Page Machine Learning Book. 2019 Aurélien Géron, Hands-On Machine Learning with Scikit-Learn, Keras, and TensorFlow. O'Reilly Media Inc., 2019
Compulsory requirement
None
Recommended requirement
Programming skills and basic knowledge of Python. Understanding of Solid Mechanics will be beneficial.

↑

Name of module	**Number of module**
Machine Learning Approaches in Structural Mechanics	11LE50MO-5722 PO 2021
Veranstaltung	
Machine Learning Approaches in Structural Mechanics	
Event type	Number
Übung	11LE50Ü-5722 PO 2021
Organizer	
Institut für Mikrosystemtechnik Simulation	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
During the course, students will complete four practice programming exercises devoted to different aspects of machine learning in mechanical engineering and solid mechanics. Students must score at least 50% on each of these practice exercises. Additionally, a detailed report on one of these exercises will be requested as a prerequisite for admission to the examination.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Responsible	
Faculty	

ECTS-Points	
Workload	
Recommended semester	2
Duration	
Pflicht/Wahlpflicht (P/WP)	

Compulsory requirement

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
			6.0		

Qualification

↑

Name of module	**Number of module**
Materials for Electronic Systems	
Event type	

ECTS-Points	6.0
Hours of week	
Recommended semester	
Frequency	
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	Number of module

Materials for Electronic Systems
Event type

ECTS-Points	
Hours of week	
Recommended semester	
Frequency	
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Responsible	
Faculty	

ECTS-Points	
Workload	
Recommended semester	2
Duration	
Pflicht/Wahlpflicht (P/WP)	

Compulsory requirement

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
			3.0		

Qualification

↑

Name of module	**Number of module**
Mechanische Eigenschaften und Degradationsmechanismen / Mechanical Properties and Degradation Mechanisms- Vorlesung	
Event type	

ECTS-Points	3.0
Hours of week	
Recommended semester	
Frequency	
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
Responsible	
JProf. Dr. Alwin Stefan Daus	
Organizer	
Institut für Mikrosystemtechnik Sensoren	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
Basic knowledge on semiconductor physics and semiconductor devices. Having completed the module micro-electronics before taking this module is recommended.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Memory Device Technology	Vorlesung		6.0	2.0	180 Stunden / hours
Memory Device Technology	Übung			2.0	

Qualification

After completion of the module, -

- the students know various classical memory and storage device types, technologies and working principles.
- the students can explain the working principle of various emerging memory device types.
- the students know about the different memory performance parameters, how they are measured and how different memory device technologies compare in those metrics
- the students know how the physical integration and realization of different memory device types is realized
- the students can explain limitations of different memory device technologies
- the students can explain how the basic material properties of each memory device type enable and affect the memory behavior
- the students can explain how emerging memristive devices are beneficial to enable in-memory computing and neuromorphic hardware

Examination achievement
Prüfungsgespräch / oral examination
Course achievement
Referat, Vortrag / Presentation

↑

Name of module	Number of module
Memory Device Technology	11LE50MO-5726 PO 2021
Veranstaltung	
Memory Device Technology	
Event type	Number
Vorlesung	11LE50V-5726 PO 2021
Organizer	
Institut für Mikrosystemtechnik Sensoren	

ECTS-Points	6.0
Workload	180 Stunden / hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
This course provides an overview on different memory device technologies. The classical memory and storage device types include static random-access memory, dynamic random-access memory, flash, hard disk drive and tape storage. The emerging memory device types include magnetic memory, phase-change memory, resistive random-access memory, ferroelectric memory and electrochemical memory. Along with the basic device concepts, the underlying physics and material properties enabling the memory functionality are explained. The various important performance parameters for memory devices are discussed. New application directions such as in-memory computing and neuromorphic computing hardware are introduced and the requirements for memory devices to be used in such scenarios are discussed.
Examination achievement
Course achievement
Presentation on implemented memory device model and functionality in circuit
Literature
1. Daniele Ielmini, Rainer Waser, "Resistive Switching: From Fundamentals of Nanoionic Redox Processes to Memristive Device Applications", 2016 Wiley-VCH, DOI: 10.1002/9783527680870 2. Jennifer Rupp, Daniele Ielmini, Ilia Valov, "Resistive Switching: Oxide Materials, Mechanisms, Devices and Operations", Springer, DOI: 10.1007/978-3-030-42424-4 3. Andrea Redaelli, Fabio Pellizzer, "Semiconductor Memories and Systems", Elsevier, ISBN 9780128209462
Compulsory requirement
None

Recommended requirement
Basic knowledge on semiconductor physics and semiconductor devices. Having completed the module micro-electronics before taking this module is recommended.

↑

Name of module	**Number of module**
Memory Device Technology	11LE50MO-5726 PO 2021
Veranstaltung	
Memory Device Technology	
Event type	Number
Übung	11LE50Ü-5726 PO 2021

ECTS-Points	
Hours of week	2.0
Recommended semester	2
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercise will recap and deepen on most important aspects of the lecture. In addition, the students will learn how to develop and incorporate emerging memory device models in a compact modeling environment. They will then simulate the behavior of such devices in simple circuits.
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	Number of module
Methoden der Materialanalyse / Methods of Material Analysis	11LE50MO-5126 PO 2021
Responsible	
Prof. Dr. Margit Zacharias	
Organizer	
Institut für Mikrosystemtechnik Nanotechnologie	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Methoden der Materialanalyse / Methods of Material Analysis	Vorlesung		3.0	2.0	90 hours

Qualification
The module gives an overview of all state of the art measurement and analysis methods for thin films and nanoscopic structures. Special emphasis will be placed on the prospects and drawbacks of each method as well as on typical limits and potential measurement artifacts. Educational objective is to enable students to find a suitable and appropriate method to measure or detect a certain material property of interest.
Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) Wenn die Teilnehmerzahl gering ist, kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert.
Course achievement
keine

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area:Materials and Fabrication

↑

Name of module	**Number of module**
Methoden der Materialanalyse / Methods of Material Analysis	11LE50MO-5126 PO 2021
Veranstaltung	
Methoden der Materialanalyse / Methods of Material Analysis	
Event type	Number
Vorlesung	11LE50V-5126
Organizer	
Institut für Mikrosystemtechnik Nanotechnologie	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 SS; 30 WS
Independent study	64 SS; 60 WS
Hours of week	2.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
The treated measurement and analysis techniques include optical, electrical, chemical and structural methods which detect and probe material properties like morphology/shape, film thickness, crystallinity, chemical composition, trace impurities, bonding configurations, bandgap, etc. Namely methods like AFM, SEM / TEM, APT, SIMS, XPS, SE, PL, FTIR, Raman, XRD, C-V / I-V, RBS and many more will be dealt with.
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components	11LE50MO-5604 PO 2021
Responsible	
Prof. Dr. Thomas Hanemann	
Organizer	
Institut für Mikrosystemtechnik Werkstoffprozesstechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine
Recommended requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components - Vorlesung	Vorlesung		3.0	2.0	90 Stunden

Qualification
Besides silicon and the established MEMS/MOEMS technology polymer materials and the related microreplication technologies are becoming more and more important for the realization and commercial success of new microcomponents and microsystems. New nanostructuring methods like 2-photon-stereolithography and others are at the threshold of leaving the laboratory status and entering market. The course will cover the large variety of polymer materials, their fundamental chemical and physical properties and the derived microstructuring and replication possibilities. Direct and indirect micro- and nanostructuring methods like deep X-ray lithography, stereolithography, laser machining, nanoimprinting and others as well as the large family of replication methods like hot embossing and injection molding will be described in detail. Master and tooling fabrication methods like electroplating, electro discharge machining as well as mechanical and laser micromachining will be presented and discussed intensely. A large number of application examples and case studies dealing with the accessible geometries, feasibility, and process characteristics will be used for the presentation of the polymer microfabrication importance.

Examination achievement
Written examination (90 minutes) if number of participants is small, oral exam (30 minutes) instead. Students will be informed in good time.
Course achievement
keine
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components	11LE50MO-5604 PO 2021
Veranstaltung	
Mikrostrukturierte Kunststoffkomponenten / Microstructured Polymer Components - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5604
Organizer	
Institut für Mikrosystemtechnik Werkstoffprozesstechnik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Contents: ■ Polymers: Fundamental chemical and physical properties ■ Fabrication of molding tools: Fabrication principles and characteristics ■ Rapid Prototyping in microsystem technology ■ Polymer replication techniques: Reaction Molding, UV-Embossing, Hot Embossing and Injection Molding: Principles, equipment, applications and case studies ■ From micro to nano: Nanoimprinting, soft lithography, nanostereolithography and other new developments
Examination achievement
see module details
Course achievement
none
Literature
■ W. Ehrfeld, Handbuch Mikrotechnik, Hanser-Verlag, München, 2002, ISBN: 3-446-21506-9 ■ W. Menz, J. Mohr, O. Paul, Microsystem Technology, Wiley-VCH, Weinheim, 2001, ISBN: 3-527-29634-4
Compulsory requirement

↑

Name of module	**Number of module**
Oberflächenanalyse / Surface Analysis	11LE50MO-5606-1 PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Oberflächenanalyse / Surface Analysis - Vorlesung	Vorlesung		3.0	2.0	90 Stunden

Qualification
XPS, TEM, FTIR, UPS, SEM, AFM, SPR, GIR, ATR, STM?? Got it? The performance of microsystems is often dominated by the nature of the surfaces involved. This course honours the great importance of surfaces and interfaces in microsystems engineering by introducing the most common techniques for surface analysis. Examples will be presented which are typical to various fields of microsystems engineering.
Examination achievement
Schriftliche Abschlussprüfung (Klausur) mit einer Dauer von 90 Minuten/written examination with a duration of 90 minutes
Course achievement
keine

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Oberflächenanalyse / Surface Analysis	11LE50MO-5606-1 PO 2021
Veranstaltung	
Oberflächenanalyse / Surface Analysis - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5606-1
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The techniques presented are grouped into three general topics which are imaging of surfaces (electron microscopy, scanning probe techniques), chemical analysis (XPS, SIMS, FTIR) of the composition of surfaces and methods for the determination of thicknesses (Ellipsometry, XRR, Surface Plasmon Spectroscopy) of layers. General topics from the surface sciences such as adhesion, wetting, and adsorption processes are also presented together with the techniques.
Examination achievement
siehe Modulebene/see module details
Course achievement
keine/none
Literature
Various materials are available on the website.
Compulsory requirement
none

↑

Name of module	**Number of module**
Oberflächenanalyse – Praktikum / Surface Analysis Laboratory	11LE50MO-5311 PO 2021
Responsible	
Dr. Oswald Prucker Prof. Dr. Jürgen Rühe	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Oberflächenanalyse – Praktikum / Surface Analysis Laboratory	Praktikum		3.0	2.0	90 hours

Qualification
In microsystems, especially those for microfluidics, surface effects can no longer be neglected due to the small volume. In many cases, the properties of the surface even dominate the behavior of the overall system. The same can be said for components that are brought into contact with biological fluids as sensors, for example. For this reason, surface analysis is of central importance for many questions relevant to microsystems technology. In the practical course, selected surface analysis techniques will be presented and their respective strengths and limitations demonstrated using examples. Examples will be chosen from questions that frequently occur in the life sciences.
Examination achievement
For each experiment, students need to hand in a protocol which will be graded. The final grade is calculated according to the weighed arithmetic mean from the individual protocol grades.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Oberflächenanalyse – Praktikum / Surface Analysis Laboratory	11LE50MO-5311 PO 2021
Veranstaltung	
Oberflächenanalyse – Praktikum / Surface Analysis Laboratory	
Event type	Number
Praktikum	11LE50P-5311

ECTS-Points	3.0
Workload	90 hours
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Topic 1: **Determination of the layer thickness and roughness of biocompatible coatings** Experiment 1: Using ellipsometry and x-ray reflectometry to determine the thickness of hydrogel coatings Topic 2: **Wetting of surfaces – Surface free energies** Experiment 2: Measurement of the contact angles of test liquids in various surfaces; Determination of the surface free energy using the Zisman method Experiment 3: Generation and characterization of microarrays on various surfaces Topic 3: **Proteins / peptides on surfaces** Experiment 4: Measurement of the adsorption of blood proteins on surfaces using Surface Plasmon Resonance Experiment 5: Characterization of the structure of protein layers using Fourier Transform Infrared Spectroscopy Topic 4: **DNA at surfaces** Experiment 6: Visualisation of DNA on mica using the Atomic Force Microscope
Examination achievement
see module details
Course achievement
none
Literature
see script
Compulsory requirement
none
Recommendation
Findet am Lehrstuhl statt

↑

Name of module	Number of module
Optimierung	11LE13MO-720 PO 2021
Responsible	
Prof. Dr. Rolf Backofen Prof. Dr. Thomas Brox	
Organizer	
Institut für Informatik Algorithmen u. Datenstrukturen Institut für Informatik Algorithmen und Komplexität Institut für Informatik Rechnerarchitektur Institut für Informatik Programmiersprache Institut für Informatik Softwaretechnik Institut für Informatik Grundl.d.künstl.Intelligenz Institut für Informatik Autonome intelligente Systeme Institut für Informatik Graphische Datenverarbeitung Institut für Informatik Mustererkennung u. Bildverarbeitung Institut für Informatik Rechnernetze u.Telematik Institut für Informatik Datenbanken u. Informationssysteme Institut für Informatik Betriebssysteme Institut für Informatik Bioinformatik Institut für Informatik Kommunikationssysteme Institut für Informatik Embedded Systems Institut für Informatik Maschinelles Lernen	
Faculty	
Mathematisches Institut Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine
Recommended requirement
Kenntnisse aus den Modulen ▪ Einführung in die Programmierung ▪ Informatik II – Algorithmen und Datenstrukturen

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Optimierung	Vorlesung		3.0	2.0	90 Stunden
Optimierung	Übung			1.0	

Qualification
Die Studierenden lernen, welche Optimierungsprobleme es gibt und wie sie gelöst werden können. Sie sollen die Schwierigkeit von Optimierungsproblemen analysieren und einschätzen lernen und in die Lage versetzt werden, die besprochenen Optimierungsverfahren in Anwendungsfällen einzusetzen.
Examination achievement
Klausur (Dauer idR 90-180 Minuten)
Course achievement
Es gibt Übungsaufgaben im regelmäßigen Rhythmus, die bearbeitet und abgegeben werden müssen. Diese werden korrigiert und mit Punkten bewertet. Die Studienleistung ist bestanden, wenn mindestens 50% der Gesamtpunkte im Semester erreicht sind.
Usability
As compulsory elective for students of the study pogram ■ M.Sc. Embedded Systems Engineering (ESE) (PO 2021) in Microsystems Engineering Concentrations Area: Materials and Fabrication ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ Master of Education Erweiterungsfach Informatik ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (Optionsbereich Individuelle Studiengestaltung) ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik Compulsory course for students of the study pogram ■ B.Sc. in Embedded Systems Engineering (PO 2018) ■ B.Sc. in Informatik (PO 2018)

↑

Name of module	**Number of module**
Optimierung	11LE13MO-720 PO 2021
Veranstaltung	
Optimierung	
Event type	Number
Vorlesung	11LE13V-720
Organizer	
Institut für Informatik Algorithmen u. Datenstrukturen Institut für Informatik Algorithmen und Komplexität Institut für Informatik Mustererkennung u. Bildverarbeitung Institut für Informatik Bioinformatik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	45
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Die Vorlesung gibt eine Einführung in die allgemeine Problematik und erklärt, wie sich viele Aufgaben der Informatik als Optimierungsprobleme formulieren lassen. Es werden die grundlegenden Verfahren und Konzepte der Optimierung vorgestellt; das Hauptaugenmerk liegt auf kontinuierlicher Optimierung. Anschließend werden Konvexität, lineare und quadratische Programme, Gradientenverfahren sowie einige approximative Verfahren behandelt. Die Vorlesung wird von größtenteils praktischen übungen begleitet. Durch theoretische und praktische Übungen wird der Stoff anschaulich vertieft.
Examination achievement
Siehe Modulebene
Course achievement
Siehe Modulebene
Literature
Nocedal-Wright: Numerical Optimization (Englisch)
Compulsory requirement
keine
Recommended requirement
Grundlagenkenntnisse in Mathematik Grundlegende Kenntnisse zu Programmierung und Algorithmen Praktische Programmierkenntnisse in Python

↑

Name of module	**Number of module**
Optimierung	11LE13MO-720 PO 2021
Veranstaltung	
Optimierung	
Event type	Number
Übung	11LE13Ü-720
Organizer	
Institut für Informatik Algorithmen u. Datenstrukturen Institut für Informatik Algorithmen und Komplexität Institut für Informatik Mustererkennung u. Bildverarbeitung Institut für Informatik Bioinformatik	

ECTS-Points	
Attendance	15
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
In den Übungen werden einzelne Verfahren eigenständig in der Sprache Python implementiert, andere Verfahren werden anhand vorhandener Bibliotheken (z.B. SciPy) ausprobiert um praktische Erfahrungen in der Anwendung dieser Verfahren zu sammeln. Für einige der Übungen sind theoretische Vorleistungen zu erbringen, um das Verfahren umsetzen zu können. Das Überprüfen fremder Lösungen ist ebenfalls Teil der Übungen.
Examination achievement
Siehe Modulebene
Course achievement
Siehe Modulebene
Compulsory requirement

↑

Name of module	Number of module
Optimierung von Fertigungsverfahren / Advanced engineering	11LE50MO-5607 PO 2021
Responsible	
Prof. Dr. Claas Müller	
Organizer	
Institut für Mikrosystemtechnik Prozesstechnologie	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none
Recommended requirement
▪ Statistical Basics ▪ Fundamentals of Manufacturing Technology ▪ Processes of microsystem technology (clean room fabrication and conventional environment)

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Optimierung von Fertigungsverfahren / Advanced engineering - Vorlesung	Vorlesung		3.0	2.0	90 Stunden

Qualification
Statistische Grundlagen zur Regelung komplexer technischer Prozesse Optimierung von Fertigungsverfahren nach unterschiedlichen Zielgrößen Erweiterung statistischer Methoden auf Führungs-und Organisationsstrukturen
Examination achievement
Klausur (Dauer 90 Minuten) Wenn Teilnehmerzahl gering, stattdessen mündliche Prüfung (Dauer 20 - max. 30 Minuten)
Course achievement
keine

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Optimierung von Fertigungsverfahren / Advanced engineering	11LE50MO-5607 PO 2021
Veranstaltung	
Optimierung von Fertigungsverfahren / Advanced engineering - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5607
Organizer	
Institut für Mikrosystemtechnik Prozesstechnologie	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Statistische Versuchsplanung
- Toleranzen und Toleranzketten
- FMEA
- Prozess und Maschinenfähigkeit
- Six Sigma
- Kaizen_PDCA
- One Piece Flow

Examination achievement

siehe Modulebene

Course achievement

keine

Literature

- George E. P. Box, Statistics for Experimenters: An Introduction to Design, Data Analysis, and Model Building (Wiley Series in Probability and Statistics)
- Manufacturing Processes & Materials Hardcover – July, 2000 by George F. Schrade
- Effective FMEAs: Achieving Safe, Reliable, and Economical Products and Processes using Failure Mode and Effects Analysis Hardcover – May 15, 2012 by Carl Carlson
- The Practical Application of the Process Capability Study: Evolving From Product Control to Process Control [Kindle Edition] Douglas B. Relyea
- The Process Improvement Handbook: A Blueprint for Managing Change and Increasing Organizational Performance Hardcover – October 15, 2013 by Tristan Boutros

Compulsory requirement

keine

Recommended requirement
Statistical Basics Fundamentals of Manufacturing Technology Processes of microsystem technology (clean room fabrication and conventional environment)

↑

Name of module	**Number of module**
Polymere in der Membrantechnik / Polymers in Membrane Technology	11LE50MO-5114 PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Polymere in der Membrantechnik / Polymers in Membrane Technology - Vorlesung	Vorlesung		3.0		90 Stunden

Qualification
Gain awareness for separation needs and sustainability impact Understand principles of separation Understand membrane fabrication and (polymeric) membrane material properties Apply polymeric surface modifications to mitigate material limitations and enable new processes
Examination achievement
-written or oral examination (duration 90/20-max. 30 min.)
Course achievement
none/ in the study program Sustaianble Materials - Polymer Science: participation and ungraded report

↑

Name of module	**Number of module**
Polymere in der Membrantechnik / Polymers in Membrane Technology	11LE50MO-5114 PO 2021
Veranstaltung	
Polymere in der Membrantechnik / Polymers in Membrane Technology - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5114
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	39
Independent study	51
Hours of week	
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The lecture will focus on polymeric materials for membrane separation technologies. The scope of applications that will be discussed ranges from water to oil & gas, biotech, dialysis to food with a focus on water filtration technologies. Creating awareness for major societal challenges like clean water supply, health care / quality of life and minimization of energy consumption and for contributions that membrane technologies can offer to sustainable solutions for these challenges will be key learning objectives. Focus will be on materials and membrane fabrication / post-modification processes as well as on the underlying principles of separation. Process engineering will be of minor importance. The lecture will concentrate on cognitive levels ‘understanding’ and ‘application’ (Bloom’s taxonomy), case studies will touch upon higher levels.
Examination achievement
see module details
Course achievement
in the study program Sustaianble Materials - Polymer Science: participation and ungraded report
Literature
Various materials are available on the website Homepage: http://www.imtek.de/cpi
Compulsory requirement
none

↑

Name of module	**Number of module**
Photovoltaische Energiekonversion für Ingenieure / Photovoltaic Energy Conversion for engineers	11LE50MO-5712 PO 2021
Responsible	
Prof. Dr. Stefan Glunz	
Organizer	
Inst. f. Nachh. Technische Systeme Photovoltaische Energiekonversion	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
Recommended requirement
Grundkenntnisse der Halbleiterphysik und -technologie sind vorteilhaft.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Photovoltaische Energiekonversion für Ingenieure / Photovoltaic Energy Conversion for engineers - Vorlesung	Vorlesung			2.0	90 Stunden

Qualification
Das Modul gibt zunächst einen allgemeinen Überblick über die Komponenten von Photovoltaischen Energiesystemen und über die Chancen und Möglichkeiten dieser Form der regenerativen Energie.

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Name of module	**Number of module**
Photovoltaische Energiekonversion für Ingenieure / Photovoltaic Energy Conversion for engineers	11LE50MO-5712 PO 2021
Veranstaltung	
Photovoltaische Energiekonversion für Ingenieure / Photovoltaic Energy Conversion for engineers - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5712

ECTS-Points	
Workload	90 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
Schriftliche oder mündliche Abschlussprüfung
Course achievement
Um zur Abschlussprüfung zugelassen zu werden, muss die Vorlesung zu jedem Vorlesungstermin besucht werden. Unentschuldigtes Fehlen führt zu einer Nichtzulassung zur Abschlussprüfung.
Compulsory requirement
Recommended requirement
Grundkenntnisse der Halbleiterphysik und -technologie sind vorteilhaft.

↑

Name of module	**Number of module**
Photovoltaische Energiekonversion für Ingenieure II / Photovoltaic Energy Conversion for engineers II	11LE50MO-5718 PO 2021
Responsible	
Prof. Dr. Stefan Glunz	
Organizer	
Inst. f. Nachh. Technische Systeme Photovoltaische Energiekonversion	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
Recommended requirement
■ Photovoltaic Energy Conversion for engineers I ■ Halbleiterphysik/Semiconductor Physics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Photovoltaische Energiekonversion für Ingenieure II / Photovoltaic Energy Conversion for engineers II - Vorlesung	Vorlesung		3.0	2.0	90 Stunden

Qualification
Schwerpunkte des vorgegangenen Moduls "Photovoltaische Energiekonversion I" waren die physikalischen Grundlagen von Solarzellen und die Technologie von Siliciumsolarzellen. Das Modul "Photovoltaische Energiekonversion II" wird sich auf alternative Technologien, Systemaspekte, Netzintegration und die Ökonomie der Photovoltaik konzentrieren.

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Name of module	**Number of module**
Photovoltaische Energiekonversion für Ingenieure II / Photovoltaic Energy Conversion for engineers II	11LE50MO-5718 PO 2021
Veranstaltung	
Photovoltaische Energiekonversion für Ingenieure II / Photovoltaic Energy Conversion for engineers II - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5718
Organizer	
Inst. f. Nachh. Technische Systeme Photovoltaische Energiekonversion	

ECTS-Points	3.0
Workload	90 Stunden
Hours of week	2.0
Recommended semester	2
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents

Die Vorlesung "Photovoltaische Energiekonversion II" beginnt mit einer knappen Zusammenfassung der vorangegangenen Vorlesung und konzentriert sich dann auf folgende Themen:

- Dünnschicht-PV (CIS, CdTe)
- Perowskitsolarzellen
- Tandemsolarzellen
- III/V-basierte PV und Konzentratoranwendungen
- Photonik für Solarzellen (Hochkonversion, Ultra-Lichteinfang)
- Systemtechnologie (Inverter, Speicherung, ...)
- Netzintegration
- Ökonomie der Photovoltaik

Examination achievement

Schriftliche oder mündliche Abschlussprüfung

Course achievement

Um zur Abschlussprüfung zugelassen zu werden, muss die Vorlesung zu jedem Vorlesungstermin besucht werden. Unentschuldigtes Fehlen führt zu einer Nichtzulassung zur Abschlussprüfung.

Literature

- P. Würfel, Physik der Solarzelle, Spektrum - Akademischer Verlag 2000
- A. Goetzberger, B. Voß und J. Knobloch, Sonnenenergie: Photovoltaik, Teubner 1997
- M.A. Green, Solar Cells, University of New South Wales 1982
- Konrad Mertens, Photovoltaik, Hanser 2011
- Jenny Nelson, The physics of solar cells, Imperial College Press 2008

Compulsory requirement

Keine

Recommended requirement
Photovoltaic Energy Conversion for engineers I Halbleiterphysik/Semiconductor Physics

↑

Name of module	**Number of module**
Polymer Processing and Microsystems Engineering	11LE50MO-5124 PO 2021
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen Institut für Mikrosystemtechnik Werkstoffprozesstechnik Institut für Mikrosystemtechnik Prozesstechnologie	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Polymer Processing and Microsystems Engineering - Vorlesung	Vorlesung		3.0	2.0	90 hours

Qualification
This course will teach students the various types of polymers in practical use today, the methods required for characterizing them, the processing techniques that are used to shape these polymers including polymer molding as well as 3D Printing. The lecture will cover fundamental aspects of polymer science and characterization as well as industrial process technology both for microsystems as well as scalable manufacturing.
Examination achievement
Oral exam with a duration of 30 minutes
Course achievement
none
Examination weight
▪ Master of Science in Sustainable Systems Engineering, Academic regulations of 2016: The grade of the module is single-weighted according to the number of its ECTS-points in the calculation of the overall grade.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication Wahlpflichtmodul für Studierende des Studiengangs ■ Master of Science in Sustainable Systems Engineering - Nachhaltige Materialien / Sustainable Materials

↑

Name of module	Number of module
Polymer Processing and Microsystems Engineering	11LE50MO-5124 PO 2021
Veranstaltung	
Polymer Processing and Microsystems Engineering - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5124
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen Institut für Mikrosystemtechnik Werkstoffprozesstechnik Institut für Mikrosystemtechnik Prozesstechnologie	

ECTS-Points	3.0
Workload	90 hours
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Polymers are ubiquitous in the 21st century. As a material class, polymers have seen an astonishing gain in academic and industrial significance since their first introduction into the market more than 140 years ago. One of the most striking advantages of polymers is their ease of processing in which they outperform almost any other material known to humankind. This lecture introduces the fundamentals of polymer processing focusing on techniques such as injection molding, hot embossing, thermoforming and nanoimprinting. These techniques represent the most important reforming processes. We will also explore additive manufacturing and 3D Printing including stereo lithography, powder-based as well as inkjet printing and fused deposition modeling. The didactical concept underlying the lecture is built on a combination of material science and instrumentation development and thus represents a holistic view onto the broad field of technical polymer processing.
Examination achievement
see module details
Course achievement
none
Literature
Various materials will be provided through the ILIAS online learning tool.
Compulsory requirement

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Name of module	Number of module
Quantenmechanik für Ingenieur*innen / Quantum Mechanics for Engineers	11LE50MO-5273 PO 2021
Responsible	
Prof. Dr. Oliver Paul	
Organizer	
Institut für Mikrosystemtechnik Materialien der Mikrosystemtechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 Stunden
Attendance	56 Stunden
Independent study	124 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine
Recommended requirement
Physik I + II / physics I + II Mathematik I + II / mathematics I + II Festkörperphysik / solid state physics Halbleiter / semiconductors Elektronik / electronics Differentialgleichungen / differential equations

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Quantenmechanik für Ingenieur*innen / Quantum Mechanics for Engineers	Vorlesung		6.0	2.0	180 hours
Quantenmechanik für Ingenieur*innen / Quantum Mechanics for Engineers	Übung			2.0	

Qualification
The goal is to introduce the students to the main effects of quantum mechanics relevant in technical micro and nano devices. Current semiconductor components in which quantum mechanics plays a role are discussed. The course successively develops the basic mathematical methods required to solve problems in one, two, and three dimensions. The understanding is deepened by exercises.

Examination achievement
Oral examination if there are 20 or fewer than 20 registered participants; written examination if there are more than 20 registered participants (minimum 60 and maximum 240 minutes). Details will be announced by the examiner in due time.
Course achievement
The course work ("Studienleistung") consists of (1) the documented, successful attempt to solve more than 60% of the homework problems (as checked weekly); "60% of the homework problems" means the fraction of the overall number of homework problems proposed during the course, not of each homework problem separately; "successful" means that the solution could be presented by the student in front of the class; (2) the presentation of a representative number of solutions of homework problems in front of the class.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Quantenmechanik für Ingenieur*innen / Quantum Mechanics for Engineers	11LE50MO-5273 PO 2021
Veranstaltung	
Quantenmechanik für Ingenieur*innen / Quantum Mechanics for Engineers	
Event type	Number
Vorlesung	11LE50V-5273
Organizer	
Institut für Mikrosystemtechnik Institut für Mikrosystemtechnik Materialien der Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Attendance	52 Stunden
Independent study	128 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
1. Introduction: historical overview, probability amplitudes, uncertainty relation 2. Wave mechanics: Schrödinger equation, separation of variables, free particle, reflection at wall, potential step, transfer matrix method, wave packets 3. Tunneling: principle, semiconductor tunneling devices, potential barriers, WKB approximation, triangular potential wall 4. Bound states, resonances, and band structure: potential well, tunneling between wells, infinite series of potential wells, 1D harmonic oscillator nanoparticles, impurity levels in semiconductors 5. Operators and state spaces, commensurate operators and quantum numbers, perturbation theory, energy matrix diagonalization 6. 3D problems, angular momentum, hydrogen atom and 3D harmonic oscillator
Examination achievement
see module details
Course achievement
see module details
Literature
A script will be handed out during the course. Material for further reading will be indicated therein.
Compulsory requirement
None
Recommended requirement
Undergraduate knowledge in the field of physics, mathematics, solid state physics, semiconductors, electronics and differential equations.

↑

Name of module	**Number of module**
Quantenmechanik für Ingenieur*innen / Quantum Mechanics for Engineers	11LE50MO-5273 PO 2021
Veranstaltung	
Quantenmechanik für Ingenieur*innen / Quantum Mechanics for Engineers	
Event type	Number
Übung	11LE50Ü-5273
Organizer	
Institut für Mikrosystemtechnik Materialien der Mikrosystemtechnik	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercises will deepen the topics treated during the lecture. They will allow the students to rethink and rework the more theoretical aspects and apply them to realistic examples inspired from real devices or use them to expand the theoretical framework of the lecture. Solution approaches to the homework problems will be presented weekly by the participants and discussed and elaborated upon with the group of colleagues under the guidance of the professor. This discursive, participative approach allows to learn more than by being presented with up-front oral or written solutions.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Undergraduate knowledge in the field of physics, mathematics, solid state physics, semiconductors, electronics and differential equations.

↑

Name of module	Number of module
Quantification of Resilience	11LE50MO-4110 PO 2021
Responsible	
Prof. Dr. Stefan Hiermaier	
Organizer	
Inst. f. Nachh. Technische Systeme Nachhaltige Ingenieursysteme	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
Any basics in any of the following areas would be helpful but are not mandatory: • system description and modelling • graphical/ semiformal modelling • product and development life cycles • classical system analysis • reliability analysis for any engineering discipline, e.g. electronics, computer science, mechanical, civil and aerospace engineering

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Resilienzquantifizierung - Vorlesung	Vorlesung		3.0	2.0	90 h

Qualification

Main learning objectives include:
1. Know main (emerging) application domains, e.g. digitalized production, transport, aerospace, AI safety, and renewable energy
2. Knowledge how to achieve acceptable overall safety (risk control), security, sustainability, and resilience of socio-technical (safety relevant and critical) systems through reliable functions
3. Knowledge and tailoring of definitions, types and effects of reliability functions
4. Relation of functional safety to related concepts for security and sustainability generation
5. Knowledge and tailoring of safety life cycle, development processes and process steps to plan, develop, verify and validate reliability or safety functions
6. Knowledge, tailoring, process-driven application, quantification and evaluation, executive conclusions development, and litigable documentation of mainly quantitative system analysis methods
7. Know how to efficiently combine and tailor modern system analysis methods

8. Know failure types and how to avoid and control them with techniques and measures for hardware and software
9. Knowledge and application of assessment quantities for reliable functions, e.g. safety integrity level (on demand or continuous), hardware failure tolerance, diagnostic coverage, safe failure fraction, complexity level
10. Knowledge of reliability prediction methods and related standards
11. Applicable knowledge of related standardization landscape

Examination achievement
The *Prüfungsleistung* is a written supervised examination at the end of the semester covering the content of the lecture and its embedded exercises contributing 100% to the final grade, duration: 90 min.
Course achievement
Expected coursework (0% contribution to the final grade): Presentation and critical review of a selected publication or of a chapter of the lecture manuscript (approx. 20 minutes including questions and answers).
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Quantification of Resilience	11LE50MO-4110 PO 2021
Veranstaltung	
Resilienzquantifizierung - Vorlesung	
Event type	Number
Vorlesung	11LE68V-4110
Organizer	
Institut für Nachhaltige Technische Systeme	

ECTS-Points	3.0
Workload	90 h
Attendance	32 h
Independent study	58 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Main contents comprise: 1. Context, basic definitions, objectives and options of resilience quantification: resilience management processes, resilience quantification and development processes 2. System (service) performance based resilience quantification 3. Method types for resilience quantification, resilience dimensions, and resilience method taxonomy 4. Qualitative and semi-quantitative resilience assessments: ontologies, process schemes, quantification and evaluation 5. Resilience dimensional order expansions and resulting quantification bounds 6. Application of classical system analysis approaches, e.g. deterministic inductive and deductive system analysis methods 7. Advanced system analysis methods, in particular time, system phase and system trajectory dependent methods such as TDFT, non-classical Markov models, Petri nets and stochastic processes 8. System graph-based and topological approaches: system definition, identification of disruption vector, response and recovery determination and response strategy optimization 9. Resilience quantification based on multiple event propagation through resilience analysis layers: heuristics vs. formalization, resilience transition matrix elements, related statistical-empirical, probabilistic, engineering and physical-simulative methods, forward and backward propagation methods 10. Input-output models, operability models: discrete and continuous 11. Coupled agent-supported engineering grid-model approaches for overall system modelling, simulation and resilience determination: operator, prosumer and consumer models; organizational, policy and framing models 12. Combination of resilience quantification approaches 13. Optimization problems in resilience engineering 14. For all resilience quantification approaches: model assumptions, application domains, application examples, typical input and output data, acceptance of modeling approach 15. Use of Machine Learning (ML) and artificial intelligence (AI) as support and stand-alone approaches for resilience quantification of systems 16. Standards, emerging standards and ongoing standardization efforts

Examination achievement
See module
Course achievement
See module
Literature

Sample literature includes:

1. Satisfying safety goals by probabilistic risk analysis, Hiromitsu Kumamoto, Springer 2007
2. Modern statistical and mathematical methods in reliability, Alyson Wilson et. al. (eds.), World Scientific, 2005
3. Mathematical and statistical methods in reliability, Bo H Lindqvist and Kyell A Doksum, World Scientific, 2003
4. Hazard analysis techniques for system safety, Clifton A. Ericson, Wiley, 2015
5. FRAM: the functional resonance analysis method, Erik Hollnagel, Ashgate, 2012
6. Synesis: The Unification of Productivity, Quality, Safety and Reliability, Erik Hollnagel, Ashgate, 2020
7. Control systems safety evaluation and reliability, William M. Gobe, 2010
8. System reliability theory: models, statistical methods and applications, Marvin Rausand, Arnljot Hoyland, Wiley-Interscience, 2004
9. Risk assessment: theory, methods, and application, Marvin Rausand, Wiley, 2011
10. Reliability of safety-critical systems: theory and applications, Marvin Rausand, Wiley, 2014
11. Risk and resilience: methods and application in environment, cyber and social domains, Eds.: Igor Linkov, Jose Manuel Palma-Oliviera, Springer, 2017
12. Functional safety for road vehicles: new challenges and solutions for e-mobility and automated driving, Hans-Leo Ross, Springer, 2016
13. Functional Safety of Machinery: Sample Questions and Solutions, Jagadeesh-Pandiyan, author’s edition, 2019
14. Functional safety in practice, Harvey T Dearden, CreateSpace Independent Publishing Platform, 2018
15. Modeling for reliability analysis: Markov modeling for reliability, maintainability, safety, and supportability analyses of complex systems, Jan van Pukite, Paul Pukite, Wiley-IEEE Press, 1998
16. Applied reliability engineering and risk analysis: probabilistic models and statistical inference, Editor(s): Ilia B. Frenkel, Alex Karagrigoriou, Anatoly Lisnianski, Andre Kleyner, John Wiley & Sons, 2013
17. Reliability engineering: theory and practice, Alessandro Birolini, Springer, 2013
18. Electronic safety systems: hardware concepts, models, calculations, Josef Börcsök, Hüthig, 2004
19. Functional Safety: Basic Principles of Safety-related Systems, Josef Börcsök, Hüthig, 2020
20. Zuverlässigkeitstechnik, Arno Meyna and Bernhard Pauli, Hanser, 2010
21. The safety critical systems handbook, David J. Smith, Butterworth-Heinemann, 2010
22. Reliability and availability engineering: modeling, analysis, and applications, Kishor S. Trivedi, Andrea Bobbio, Cambridge University Press, 2017
23. Embedded Software Development for Safety-Critical Systems, Chris Hobbs, CRC Press, 2019
24. Dynamic Probabilistic Systems, Volume I: Markov Models, Ronand A. Howard, Dover publications, 2012
25. Dynamic Probabilistic Systems, Volume II: Semi-Markov and Decision Processes, Ronand A. Howard, Dover publications, 2013
26. Fault-Tolerant Systems, Israel Koren, C. Mani Krishna, Morgan Kaufmann Publisher, 2020
27. Semi-Markov Processes: Applications in System Reliability and Maintenance, Franciszek Grabski, Elesevier, 2014
28. A Primer in Petri Net Design, Wolfgang Reisig, Springer, 1992
29. Ereignisdiskrete Systeme: Modellierung und Analyse dynamischer Systeme mit Automaten, Markovketten und Petrinetzen, Jan Lunze, De Gruyter, 2017
30. System Modeling and Control with Resource-Oriented Petri Nets, MengChu Zhou, Routledge, 2017
31. Formal Methods in Computer Science, Jiacun Wang, William Tepfenhart, Taylor & Francis, 2019

Further information:
Sample related standards for information
https://www.iec.ch/functionalsafety/
https://www.iso.org/standard/68383.html
https://www.iso.org/standard/70939.html

Recent publications: https://scholar.google.com/citations?user=luyHvrkAAAAJ&hl=en
Compulsory requirement
None
Recommended requirement
Any basics in any of the following areas would be helpful but are not mandatory: • system description and modelling • graphical/ semiformal modelling • product and development life cycles • classical system analysis • reliability analysis for any engineering discipline, e.g. electronics, computer science, mechanical, civil and aerospace engineering
Teaching method
Lecture with embedded exercises including contextualization and discussion of short students’ journal paper presentations.

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Name of module	Number of module
Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers	11LE50MO-5804 PO 2021
Responsible	
Prof. Dr. Claas Müller Prof. Dr.-Ing. Bastian Rapp	
Organizer	
Institut für Mikrosystemtechnik Prozesstechnologie	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	42 Stunden
Independent study	48 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers	Praktikum		3.0	3.0	

Qualification
The Goal of the Cleanroom Lab Course is to learn Cleanroom behaviour and processing and the creation of a high quality lab report.
Examination achievement
The grade of the lab course is derived from the average of 6 short tests with evaluation of the practical skill of the student by the supervisor (50%) and a lab report (50%).
Course achievement
none
Examination weight
■ Master of Science im Fach Embedded Systems Engineering Prüfungsordnungsversion 2012: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. ■ Master of Science im Fach Microsystems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers	11LE50MO-5804 PO 2021
Veranstaltung	
Reinraumlaborkurs für Ingenieure / Clean Room Laboratory for Engineers	
Event type	Number
Praktikum	11LE50P-5804

ECTS-Points	3.0
Attendance	42 Stunden
Hours of week	3.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Cleanroom behavior and processing:
1. Wafer handling
2. Lithography sequence
3. Cleaning
4. Metal deposition (physical vapour deposition)
5. Profilometry
6. Lift-Off
7. Wafer backside processing
8. Electroplating
9. Characterization
10. Acquisition of relevant processing data and recording

Examination achievement

see module details

Course achievement

see module details

Literature

A script is provided and kept up-to-date.
- C. Müller, MST Technologies and Processes, lecture
- W. Menz, J. Mohr, O. Paul, Microsystems Technology, Wiley VCH
- M. Madou, Fundamentals of Microfabrication, CRC Press
- S. M. SZE, Physics of Semiconductor Devices, Wiley VCH
- J. W. Dini, Electrodeposition, Noyes Publications

Compulsory requirement

↑

Name of module	**Number of module**
Soft Robotics	11LE50MO-5374 PO 2021
Responsible	
JProf. Dr. Edoardo Milana	
Organizer	
Institut für Mikrosystemtechnik Professur für Soft Machines	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden/hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Soft Robotics	Vorlesung		6.0	2.0	180 hours
Soft Robotics - Projekt	Projekt			2.0	

Qualification
The objective of this course it to provide students of engineering with the basics of Soft Robotics. Thus, the following topics will be addressed: - design and modeling of soft robots - soft actuation principles - materials and fabrication processes - control of soft robots - multifunctional embodiement
Examination achievement
oral examination oral presentation The final grade will be a weighted average of the project presentation (30%) and oral exam (70%)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication ■ M.Sc. Informatik / Computer Science (PO 2020), in Spezialvorlesung | Specialization Courses Wahlpflichtmodul für Studierende des Studiengangs ■ Master of Science in Sustainable Systems Engineering - Interdisciplinary Profile

↑

Name of module	**Number of module**
Soft Robotics	11LE50MO-5374 PO 2021
Veranstaltung	
Soft Robotics	
Event type	Number
Vorlesung	11LE50V-5374
Organizer	
Institut für Mikrosystemtechnik Professur für Soft Machines	

ECTS-Points	6.0
Workload	180 hours
Hours of week	2.0
Recommended semester	3
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The students will learn how to design, fabricate and control robots made of soft and deformable materials. Models of soft manipulators based on beam theory and piecewise constant strain approximation will be introduced. We will study the main soft actuation mechanisms, such as inflatable actuators, electroactive polymers, magnetorheological elastomers, liquid crystal elastomers. Different manufacturing techniques will be analysed, in the context of polymer molding and additive manufacturing. Further, we will see some examples of model-based control for soft robots. Finally, the concept of multifunctional embodiement of sensing, actuation, control and energy will be discussed. During the course there will be a project assignment, where the students will be divided in groups and will be given a design challenge for a soft robotic system with specific requirements in terms of operational environment and locomotion modes.
Examination achievement
See module level
Course achievement
See module level
Literature
Della Santina, Cosimo, et al. "Soft robots." Encyclopedia of Robotics 489 (2020). Rus, Daniela, and Michael T. Tolley. "Design, fabrication and control of soft robots." Nature 521.7553 (2015): 467-475. Gorissen, Benjamin, et al. "Elastic inflatable actuators for soft robotic applications." Advanced Materials 29.43 (2017): 1604977. Suzumori et al "The Science of Soft Robots: Design, Materials and Information Processing", Springer (2023)
Compulsory requirement
None
Recommended requirement
Continuum Mechanics (Solid and Fluid), Electromagnetism, Thermodynamics

↑

Name of module	**Number of module**
Soft Robotics	11LE50MO-5374 PO 2021
Veranstaltung	
Soft Robotics - Projekt	
Event type	Number
Projekt	11LE50P-5374
Organizer	
Institut für Mikrosystemtechnik Professur für Soft Machines	

ECTS-Points	
Hours of week	2.0
Recommended semester	3
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Solar Energy	11LE68MO-8060 PO 2021
Responsible	
Prof. Dr. Stefan Glunz	
Organizer	
Institut für Nachhaltige Technische Systeme Inst. f. Nachh. Technische Systeme Photovoltaische Energiekonversion	
Faculty	
Technische Fakultät Institut für Nachhaltige Technische Systeme	

ECTS-Points	6.0
Workload	180 h
Recommended semester	1
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
Basic understanding of physics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Solare Energie - Vorlesung	Vorlesung		6.0	4.0	180 h
Solare Energie / Solar Energy	Übung			1.0	

Qualification
Students will be able to understand the fundamentals and different technology variants of solar energy conversion such as photovoltaics and solar thermal. They will know the relevant physical background, technical characteristics, materials and designs used. The lecture will cover the component, product and system level. Furthermore, students will understand trends of further development as well as limitations and possibilities in application of solar energy.
Examination achievement
Written supervised exam, duration: 120 min.
Course achievement
Regular attendance of the exercise workshops according to §13 (2) of the General Examination Regulations for the Master of Science and submission of exercise sheets.

Usability
Mandatory elective module for students of the study program ■ M.Sc. in Sustainable Systems Engineering (PO 2021) in the technical concentration area *Energy Systems Engineering* Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Solar Energy	11LE68MO-8060 PO 2021
Veranstaltung	
Solare Energie - Vorlesung	
Event type	Number
Vorlesung	11LE68V-8060
Organizer	
Inst. f. Nachh. Technische Systeme Photovoltaische Energiekonversion	

ECTS-Points	6.0
Workload	180 h
Attendance	60 h
Independent study	120 h
Hours of week	4.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	
Group size	50

Contents

- Solar Energy - Theoretical and Technical Energy Potential (black body radiation, Carnot cycle, maximum efficiencies, …)
- Solar Energy Technologies - Tapping the sun’s energy (overview of conversion technologies, system boundaries, seasonal fluctuation, ...)
- Photovoltaics - Physics of Solar Cells (introduction to semiconductors, Fermi levels, IV curves, conversion efficiency, quantum efficiency …)
- Photovoltaics - Technology Review (short introduction to the structure and technology of crystalline silicon solar cells)
- Solar Thermal - Physics of Solar Collectors (basics of thermo dynamics, fluid dynamics, absorption, emission, power output and other performance criteria)
- Solar Thermal - Technology Review (from low temperature applications up to power plants - examples)
- Heat pumps - Thermodynamics, electrical and thermal driven heat pumps and chillers, main components (compressor, evaporator, condenser etc.), system configurations (layout, sources, storages, control strategies etc.)
- Heat pumps: field tests and best case examples - Heat pumps and smart grid interaction, Heat pumps and PV, Heat pumps + solar thermal, storage integration)

The lecture will be accompanied by weekly exercises and simulation workshops to deepen the lecture's content and to apply state-of-the-art simulation software to design and describe complete energy systems.

Examination achievement

See module

Course achievement

See module

Literature
■ Duffie-Beckman: Solar Engineering of Thermal Processes, ■ V. Quaschning: Understanding Renewable Energy, ■ Peuser FA, Remmers K, et.al.: Solar thermal systems ■ P. Würfel, Physik der Solarzelle, Spektrum - Akademischer Verlag 2000 ■ Goetzberger, B. Voß und J. Knobloch, Sonnenenergie: Photovoltaik, Teubner 1997 ■ M.A. Green, Solar Cells, University of New South Wales 1982 ■ K. Mertens, Photovoltaik, Hanser 2011 ■ J. Nelson, The physics of solar cells, Imperial College Press 2008
Compulsory requirement
None
Recommended requirement
Basic understanding of physics
Teaching method
Lecture with accompanied, weekly exercise

↑

Name of module	**Number of module**
Solar Energy	11LE68MO-8060 PO 2021
Veranstaltung	
Solare Energie / Solar Energy	
Event type	Number
Übung	11LE68Ü-8060
Organizer	
Inst. f. Nachh. Technische Systeme Photovoltaische Energiekonversion	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
▪ The lecture will be accompanied by a weekly exercise to deepen the understanding of the lecture's content and to discuss further details
Examination achievement
See module
Course achievement
See module
Compulsory requirement

↑

Name of module	**Number of module**
Techniken zur Oberflächenmodifizierung / Surface coating Techniques	11LE50MO-5109 PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Techniken zur Oberflächenmodifizierung / Surface coating Techniques	Vorlesung		3.0	2.0	90 Stunden

Qualification
This module describes all aspects of surface modification as often used in microsystems engineering. It tackles questions on the chemistry of the various approaches and discusses the advantages and shortcomings of a number of methods. Among the techniques presented are high energy surface oxidation techniques (chemical modification, flame treatment, corona discharge or plasma) as well as more elaborate approaches such as sef-assembled monolayers. Special emphasis is given to the use of polymers for coartings.
Examination achievement
Schriftliche Abschlussprüfung (Klausur) mit einer Dauer von 90 Minuten
Course achievement
keine

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Techniken zur Oberflächenmodifizierung / Surface coating Techniques	11LE50MO-5109 PO 2021
Veranstaltung	
Techniken zur Oberflächenmodifizierung / Surface coating Techniques	
Event type	Number
Vorlesung	11LE50V-5109
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Among the techniques presented are high energy surface oxidation techniques (chemical modification, flame treatment, corona discharge or plasma) as well as more elaborate approaches such as self-assembled monolayers. Special emphasis is given to the use of polymers for coatings and techniques will be described that yield surface attached polymer monolayers and multilayer assemblies. Examples from current research topics will be discussed.
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
none

↑

Name of module	**Number of module**
Verbindungshalbleiter / Compound semiconductor devices	11LE50MO-5111_PO 20091
Responsible	
Prof. Dr. Oliver Ambacher Björn Christian	
Organizer	
Inst. f. Nachh. Technische Systeme Prof. f. Leistungselektronik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Verbindungshalbleiter / Compound semiconductor devices	Vorlesung		3.0	2.0	90 Stunden

Qualification
Das Ziel der Vorlesung Verbindungshalbleiter ist es, ein bildhaftes Verständnis der physikalischen Zusammenhänge in Halbleitermaterialien zu fördern, das es den Studenten ermöglicht sich in unbekannte Materialien anhand deren Gitterstruktur und Elektronenkonfiguration schnell einzuarbeiten. Im Anschluss kennen die Prüflinge die Unterschiede von Verbindungshalbleitern und klassischen Halbleitermaterialien wie zum Beispiel Silizium und können diese miteinander vergleichen. Besondere Materialeigenschaften der Verbindungshalbleiter wie Pyroelektrizität und Piezoelektrizität wurden verstanden und deren Relevanz für Bauelemente ist nun bekannt. Zudem kennen Studenten nach Besuch der Vorlesung die Grundlagen verbindungshalbleiterbasierter Bauelemente wie High-Electron-Mobiliy-Transistoren (kurz HEMTs), Light Emitting Diodes (LEDs), Quantum Cascade Lasers (QCLs) und verschiedener Detektoren für Infrarot- und UV-Licht und können eingrenzen welche Verbindungshalbleiter für welche Anwendungen in Frage kommen und können dies auch begründen.
Examination achievement
mündliche Abschlussprüfung (90 Minuten)
Course achievement
keine

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	Number of module
Verbindungshalbleiter / Compound semiconductor devices	11LE50MO-5111_PO 20091
Veranstaltung	
Verbindungshalbleiter / Compound semiconductor devices	
Event type	Number
Vorlesung	11LE50V-5111
Organizer	
Inst. f. Nachh. Technische Systeme Prof. f. Leistungselektronik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Spannende und neue physikalische Eigenschaften ergeben sich aus den immer kleiner werdenden Abmessungen von mechanischen, elektrischen und optischen Bauelementen aus Verbindungshalbleitern (GaN, GaAs, InP). In einer Einführung in die Welt der Verbindungshalbleiter-Mikrosysteme wird die Physik sowie die Technologie zur Herstellung von kleinsten Leuchtdioden und Lasern, mikromechanischen Filtern und Resonatoren sowie kleinsten Sensoren zur Analyse biologischer Prozesse vorgestellt. Neuartige Bauelemente aus Verbindungshalbleitern werden in ihrer Funktionsweise erläutert und ihre Relevanz für unser tägliches Leben dargestellt.
Examination achievement
siehe Modulebene
Course achievement
keine
Literature
Nanoelectronics and Information Technology Rainer Waser (Ed.) 2003 WILEY-VCH Verlag GmbH & Co ISBN 3-527-40363-9 Nanophysik und Nanotechnologie Horst-Günter Rubahn 2002 Teubner GmbH ISBN 3-519-00331-7
Compulsory requirement
Grundkenntnisse in Halbleiter- und Festkörperphysik

Recommended requirement
Bachelor-Abschluss (Ingenieur- oder Naturwissenschaften)

↑

Name of module	**Number of module**
Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld	11LE50MO-5101 PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Institut für Mikrosystemtechnik Werkstoffprozesstechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 h
Recommended semester	3
Duration	
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none
Recommended requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld - Vorlesung	Vorlesung		3.0	2.0	90 Stunden

Qualification
This module describes the issues encountered at the transition from the world of Microsystems to the nanoworld. It aims at an understanding of the principle concepts for both worlds and describes current trends and problems in the field. It is also attempted to give an outlook for future research within the boundaries of physics.
Examination achievement
Schriftliche Abschlussprüfung mit einer Dauer von 90 Minuten
Course achievement
keine

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld	11LE50MO-5101 PO 2021
Veranstaltung	
Von Mikrosystemen zur Nanowelt / From Microsystems to the Nanoworld - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5101
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

1. INTRODUCTION
What is nanotechnology? The long way of science to nanotechnology and nanoengineering: a survey. The current aspects of nanoengineering: beyond terabyte hard drives. Future aspects: Molecular motors and engines. Nano robots and nano machinery.

2. FOUNDATIONS
The physics governing properties of objects on the micro- and nano-scale. Principles of manufacturing nanometer scale devices: Nature’s strategy: biomotors based on proteins - something the human body already does, top-down approach: miniaturization of macro-world principles to ever smaller scales, bottom-up strategy: from synthesizing simple compounds consisting of a few atoms to nanoengines. Examples of man-made nanostructures. Properties of novel materials, Strategies for visualization and object handling in the nano world.

3. PROBLEMS
From Micro to Nano: what’s different. Physical and societal limits of nano engineering.

Examination achievement

siehe Modulebene

Course achievement

keine

Compulsory requirement

none

Recommended requirement

none

↑

Name of module	**Number of module**
Dynamics of Materials: Material Characterization	11LE68MO-5118 PO 2021
Responsible	
Prof. Dr. Stefan Hiermaier	
Organizer	
Inst. f. Nachh. Technische Systeme Nachhaltige Ingenieursysteme	
Faculty	
Technische Fakultät Institut für Nachhaltige Technische Systeme	

ECTS-Points	6.0
Workload	180 h
Recommended semester	2
Duration	1 semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Werkstoffdynamik: Werkstoffcharakterisierung - Vorlesung	Vorlesung		6.0	2.0	180 h
Werkstoffdynamik: Werkstoffcharakterisierung / Dynamics of Materials: Material Characterization	Übung		6.0	2.0	

Qualification
Aim of the course is the knowledge of experimental and numerical basics on the mechanical behaviour of materials under dynamic loading conditions. It enables the students in deriving strain-rate dependent stress-strain relations and in implementing the resulting constitutive models into numerical codes. General aim is the basic ability for experimental characterization and numerical modelling of dynamic material behaviour.
Examination achievement
Written supervised exam, duration: 90 min.
Course achievement
None

Usability
Mandatory elective module for students of the study program ■ M.Sc. in Sustainable Systems Engineering (PO 2021) in the technical concentration area *Resilience Engineering* Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Dynamics of Materials: Material Characterization	11LE68MO-5118 PO 2021
Veranstaltung	
Werkstoffdynamik: Werkstoffcharakterisierung - Vorlesung	
Event type	Number
Vorlesung	11LE68V-5118
Organizer	
Inst. f. Nachh. Technische Systeme Nachhaltige Ingenieursysteme	

ECTS-Points	6.0
Workload	180 h
Attendance	52 h
Independent study	128 h
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Materials Characterisation: ■ Static and dynamic testing of materials ■ Strain rate as a measure for dynamic material behaviour ■ Use of elastic waves for materials testing ■ Strain-rate dependent elasticity, plasticity, and failure ■ Mathematical modelling of material failure ■ Shock waves in solids ■ Equations of state and the total stress tensor ■ Nonlinear Equations of state Numerical modelling of dynamic deformation ■ Spatial and Time Discretization of dynamic deformation of solids ■ Finite differences for space and time ■ Basics of the Finite Element method ■ Implicit and explicit time integration ■ Basics of meshfree discretization methods
Examination achievement
See module
Course achievement
See module
Literature
■ S. Hiermaier, "Structures under Crash and Impact", Springer, 2008.
Compulsory requirement
None

Recommended requirement
None
Teaching method
Lecture + exercise

↑

Name of module	**Number of module**
Dynamics of Materials: Material Characterization	11LE68MO-5118 PO 2021
Veranstaltung	
Werkstoffdynamik: Werkstoffcharakterisierung / Dynamics of Materials: Material Characterization	
Event type	Number
Übung	11LE68Ü-5118
Organizer	
Inst. f. Nachh. Technische Systeme Nachhaltige Ingenieursysteme	

ECTS-Points	6.0
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Exercises will utilize freely available Finite-Element codes (currently: Ansys Student) to study specific applications of the theoretical knowledge established in the lectures. We will work through a series of applied examples demonstrating different material behaviour, e.g. reversible elastic or permanent plastic deformation. Different solution methods for quasi-static and time-dependent phenomena will be explored. The need for simulation as a tool to interpret experimental data will be demonstrated in case of elastic wave propagation for the Split-Hopkinon Bar Method. Students are expected to present solutions to exercises in front of the class.
Examination achievement
See module
Course achievement
See module
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
MSE Study Project in Concentration Materials and Fabrication	11LE50MO-SP MSE MF
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Faculty	
Technische Fakultät	

ECTS-Points	9.0
Workload	270 Stunden /hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
keine | none
Recommended requirement
allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Ingenieurswissenschaften, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general fundamental mathematical knowledge, practical and theoretical foundations in Engineering Sciences, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload

Contents
In this module students get involved in the actual research process of the chosen work group/chair in the area of Materials and Fabrication. Depending on their personal field of interest and their expertise in various research and teaching areas offered at the Department of Microsystems Engineering, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work experimentally and constructively in projects. Students acquire the ability to familiarize themselves with new engineering problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be trained.
Qualification
Examination achievement
Depending on the specific project: written research paper or creation of demonstrators including a sufficient documentation or presentation and subsequent discussion

Course achievement
Regular attendance in (team) discussions or meetings with the supervisor. Self- organizing the given tasks, doing background research, presentation of results
Recommendation
Language is usually English, but might be negotiable (changed to German). Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.)

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Name of node	Number of node
Biomedical Engineering	11LE50KO-WP-MSc-986-2021 WP2 BE
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

↑

Name of module	**Number of module**
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing	11LE50MO-5303 PO 2021
Responsible	
Prof. Dr. Ulrich Hofmann	
Organizer	
Medizinische Fakultät	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
Prerequisite to be able to follow this module is a thorough understanding of classical signal processing. Strongly recommended is the knowledge of one „programming“ language like Python (preferably), Matlab (or Octave) or even IDL (not supported). It is strongly recommended to complete the module "Neuroprostetics" prior to taking this course.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing - Vorlesung	Vorlesung		3.0	2.0	90 hours
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing - Übung	Übung			1.0	

Qualification
Participants will learn to interpret and analyze biological signals of high bandwidth. They will ■ gain a deep knowledge of feature extraction methods, ■ utilize selected classification methods and ■ decision making methods.

Examination achievement
Written documentation in the form of a short scientific paper (5-10 pages) and oral presentation (30 minutes) about the software developped. The module grade is based on the written documentation (50%) and the oral presentation (50%).
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing	11LE50MO-5303 PO 2021
Veranstaltung	
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5303

ECTS-Points	3.0
Workload	90 hours
Attendance	45 hours
Independent study	45 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Selected sources of biosignals:
- ECG
- EMG
- EOG
- EEG
- LFP
- Multi- and Single Unit Neuronal Records

Selected feature extraction methods:
- Nyquist Sampling and standard conditioning
- (adaptive) Filtering
- Fouriertransform and related methods:
  - Fourier Coefficients,
  - Short Term Fourier Transform
  - Gabor Functions
  - Discrete Cosinus Transform
  - Short Term Fourier Transform
- Coarse Graining Signal Analysis
- Bispectrum and Bi-Coherence
- Empirical Mode Decomposition (Hilbert-Huang Transformation)
- Undecimated Wavelet Transform and Polyphase Matrices
- The Teager Operator
- Compressed Sensing
- Kernel Methods and Spike Detections

Selected Classification and Decision Methods
- Principal Components
- Independent Component Analysis
- LDA, QDA, RFD

- Gaussian Mixture Models
- SVM, soft margin SVM
- Hidden Markov Modells
- Maximum Relevance Minimum Redundancy
- Ensemble Methods
- Bagging

Examination achievement
see module details
Course achievement
None
Compulsory requirement
None
Recommended requirement
Prerequisite to be able to follow this module is a thorough understanding of classical signal processing. Strongly recommended is the knowledge of one „programming“ language like Python (preferably), Matlab (or Octave) or even IDL (not supported). It is strongly recommended to complete the module "Neuroprosthetics" prior to taking this course.

↑

Name of module	Number of module
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing	11LE50MO-5303 PO 2021
Veranstaltung	
Ausgewählte Problemstellungen in Biosignalverarbeitung / Selected Problems in Biosignal Processing - Übung	
Event type	Number
Übung	11LE50Ü-5303

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
See lecture
Course achievement
None
Literature
tba
Compulsory requirement

↑

Name of module	**Number of module**
Biologie für Ingenieurinnen und Ingenieure	11LE50MO-780 PO 2021
Responsible	
Prof. Dr. Ulrich Egert	
Organizer	
Institut für Mikrosystemtechnik Biomikrotechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	5
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine
Recommended requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Biologie für Ingenieurinnen und Ingenieure	Vorlesung		3.0	2.0	90 Stun-den
Biologie für Ingenieurinnen und Ingenieure	Übung			1.0	

Qualification
Das Ziel dieses Moduls ist es, das Verständnis für grundlegende biomedizinische Konzepte, Prozesse und Strukturen, die definieren, oder Einfluss auf die Funktion der technischen Komponenten für biomedizinische Anwendungen zu vermitteln.
Examination achievement
Klausur (90 Min.)
Course achievement
keine

Usability
Compulsory elective module for students of the study program ▪ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ▪ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ▪ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Biologie für Ingenieurinnen und Ingenieure	11LE50MO-780 PO 2021
Veranstaltung	
Biologie für Ingenieurinnen und Ingenieure	
Event type	Number
Vorlesung	11LE50V-BScMST-780
Organizer	
Technische Fakultät Institut für Mikrosystemtechnik Biomikrotechnik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30 Stunden
Independent study	60 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Die Vorlesungsreihe vermittelt die Grundlagen der verschiedenen biologischen Prozesse und Strukturen mit dem Ziel, den Rahmen der Messung von Signalen und die Anwendung von Mikrosystemen in der Biologie und Medizin zu beschreiben. Wir legen Wert auf Prozesse, die

- Einfluss auf die Erzeugung und die Eigenschaften der Signale meßbar Mikrosysteme, z.B. klinisch relevanten Schlüsselmoleküle, elektrische Signale in Muskel- und Nervensysteme, Sauerstoffversorgung des Blutes usw.
- Einfluss auf die Nutzbarkeit von MST compontentes, beispielsweise Sensoren oder Implantaten, wie zB durch Korrosion, Gewebereaktionen, Verkapselung, Veränderungen der Messbedingungen usw.
- typische Anwendungsbereiche der MST-Komponenten sind, beispielsweise relevant implantierbare Sensoren, Prothesen, Neurotechnologie, usw.

Im Rahmen der Vorlesungen werden wir einen ziemlich breiten Überblick zu präsentieren, mit einer gewissen Vorliebe für elektrische Biosignale. Notwendigerweise die Tiefe, durch die wir diese Themen behandeln muss begrenzt werden.

Themenschwerpunkte sind:

- grundlegende Konzepte zugrunde liegenden biologischen Geweben und ihre Funktionen
- Zellstruktur und Wachstum, den Stoffwechsel, die Zelldifferenzierung und specilization
- Grundlagen der Genetik
- Funktionssysteme des menschlichen Körpers
- Biophysik elektrischer Potentiale
- Neuronale Netze und deren Signale
- sensorische Systeme
- Fundamente von Lernen und Gedächtnis
- Energiestoffwechsels und der Ausscheidung
- Atmung
- Herz-Kreislauf-System

Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
keine
Recommended requirement
keine

↑

Name of module	**Number of module**
Biologie für Ingenieurinnen und Ingenieure	11LE50MO-780 PO 2021
Veranstaltung	
Biologie für Ingenieurinnen und Ingenieure	
Event type	Number
Übung	11LE50Ü-BScMST-780-PO 2018

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
Biointerfaces I - Basics for Bioanalytical Systems	11LE50MO-5406_1 PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Biointerfaces I - Basics for Bioanalytical Systems	Vorlesung		3.0	2.0	90 hours

Qualification
The learning objective is the understanding of the basic methods for the analysis of biomolecules and their technical requirements. The participant will acquire an understanding of methods of DNA analysis (e.g. PCR) and protein analysis (e.g. ELISA) and will be able to plan such analyses (equipment / execution).
Examination achievement
Written exam (90 minutes)
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Biointerfaces I - Basics for Bioanalytical Systems	11LE50MO-5406_1 PO 2021
Veranstaltung	
Biointerfaces I - Basics for Bioanalytical Systems	
Event type	Number
Vorlesung	11LE50V-5406_1
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
■ DNA analytics (enzymes / methods / devices) ■ Various PCR methods ■ DNA Fingerprinting ■ Protein analysis (enzymes / methods / devices) ■ Antibody based detection systems (ELISA)
Examination achievement
see module details
Course achievement
None
Literature
Materials are provided via the ILIAS system. An ILIAS page will be created and made available to students before the start of lectures.
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Biointerfaces II - Interfaces for Bioanalytical Systems	11LE50MO-5407_1 PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Biointerfaces II - Interfaces for Bioanalytical Systems	Vorlesung		3.0	2.0	90 hours

Qualification
Biochip technologies play an important role in the miniaturization and parallelization of bioanalytical techniques. They combine microbiological methods with microsystems technology. Students will understand the requirements for integrating modern bioanalytical methods into microsystems. Emphasis will be placed on the design of bioanalytical surfaces and surface architectures, and students will learn how such concepts can be applied to chip-based detection methods.
Examination achievement
Written examination (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Biointerfaces II - Interfaces for Bioanalytical Systems	11LE50MO-5407_1 PO 2021
Veranstaltung	
Biointerfaces II - Interfaces for Bioanalytical Systems	
Event type	Number
Vorlesung	11LE50V-5407_1
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
■ Interaction of surfaces with biological environments ■ Design criteria for bioanalytical surfaces and interfaces ■ Methods and techniques of biochip fabrication ■ Biochips for the analysis of nucleic acids ■ Protein biochips ■ Complex biochip techniques
Examination achievement
see module details
Course achievement
None
Literature
Materials are provided via the ILIAS system. An ILIAS page will be created and made available to students before the start of lectures.
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Biomedizinische Messtechnik I / Biomedical Instrumentation I	11LE50MO-5301 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Biomedizinische Messtechnik I / Biomedical Instrumentation I - Vorlesung	Vorlesung		3.0	2.0	90 hours
Biomedizinische Messtechnik I / Biomedical Instrumentation I - Übung	Übung			1.0	

Qualification
The objective of the module is to teach students the fundamental knowledge of biological and medical as well as physical and engineering processes to be able to acquire bioelectrical signals from the human body. Scientific and engineering knowledge from the whole signal chain between the biological source over the recording system is introduced including aspects of interferences and patient safety. Applications from cardiology (ECG) and neurology (EEG) as most prominent applications in clinical medicine are used as examples. The module teaches the students of microsystems engineering the fundamental anatomical, physiological and technical terms of biomedical terms with respect to bioelectrical signals. The students will get an overview of the application areas of the different methods and the technical background of the underlying measurement principles and measurement systems. The accompanying exercises consolidate the theoretical background and guide the students to independent handling of topics in the field of biomedical engineering.
Examination achievement
Oral examination (30 minutes)

Course achievement
The exercises are considered passed if 50% of maximum points will be achieved in each of the three tests that are written in the exercises with prior notice.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Biomedizinische Messtechnik I / Biomedical Instrumentation I	11LE50MO-5301 PO 2021
Veranstaltung	
Biomedizinische Messtechnik I / Biomedical Instrumentation I - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5301
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	39 hours
Independent study	51 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The course introduces different aspects of the recording of bioelectrical signals starting with the nerve and including amplifier design. It presents the most important medical diagnosis methods in the field of bioelectrical signals. In detail, the following topics will be covered:

- Origin of bioelectrical signals
- Electrochemistry of electrodes
- Acute and chronic applications of electrodes
- Recording and amplification of bioelectrical signals
- Interference and artefacts
- Bioelectrical signals of peripheral nerves and the muscle
- Electrical signals of the heart (ECG)
- Cardiac pacemakers and implantable defibrillators
- Technical safety of medical devices

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.

Examination achievement

see module details

Course achievement

see module details

Literature

Actual copies of the slides will be delivered accompanying to the lectures.
Literature:
German

1. Schmidt, Robert F., Lang, Florian, Thews, Gerhard (Hrsg.): Physiologie des Menschen, 29. Auflage. Heidelberg: Springer Medizin Verlag, 2005

English 1. Bronzino, Joseph D. (Hrsg.): The Biomedical Engineering Handbook, Volume 1 (and 2), Second Edition. Boca Raton: CRC Press 2000 / Heidelberg: Springer-Verlag, 2000 2. Enderle, John, Blanchard, Susan, Bronzino, Joseph (Hrsg.): Introduction to Biomedical Engineering, Second Edition. Burlington, San Diego, London, Elsevier, 2005
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Biomedizinische Messtechnik I / Biomedical Instrumentation I	11LE50MO-5301 PO 2021
Veranstaltung	
Biomedizinische Messtechnik I / Biomedical Instrumentation I - Übung	
Event type	Number
Übung	11LE50Ü-5301
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Biomedizinische Messtechnik II / Biomedical Instrumentation II	11LE50MO-5302 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Biomedizinische Messtechnik II / Biomedical Instrumentation II - Vorlesung	Vorlesung		3.0	2.0	90 hours
Biomedizinische Messtechnik II / Biomedical Instrumentation II - Übung	Übung			1.0	

Qualification
The objective of the module is to teach students the fundamental knowledge of biological and medical as well as physical and engineering processes to be able to acquire non-electrical measurement categories out of the human body and to impart knowledge about the technical and medical background of the most important imaging methods in medicine. The module teaches the students of microsystems engineering the fundamental anatomical, physiological and technical terms of biomedical terms with respect to cardiovascular diagnosis and imaging techniques. The students will get an overview of the application areas of the different methods and the technical background of the underlying measurement principles and measurement systems. The accompanying exercises consolidate the theoretical background and guide the students to independent handling of topics in the field of biomedical engineering
Examination achievement
Oral examination (30 minutes)

Course achievement
The exercises are considered passed if 50% of maximum points will be achieved in each of the three tests that are written in the exercises with prior notice.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Biomedizinische Messtechnik II / Biomedical Instrumentation II	11LE50MO-5302 PO 2021
Veranstaltung	
Biomedizinische Messtechnik II / Biomedical Instrumentation II - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5302
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	45 hours
Independent study	45 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The course introduces methods to acquire non electrical cardiovasular parameters as well as the most important medical imaging techniques.

- Measurement of cardiovascular parameters: blood pressure, physiology, pressure, measurement according to Riva Rocci & oscillometric
- Measurement of cardiovascular parameters: blood flow, electromagnetic measurement principle
- Measurement of cardiovascular parameters: blood flow, ultrasound measurement principle
- Imaging techniques: x-ray
- Imaging techniques: systems theory of imaging systems, digital signal processing
- Imaging techniques: computer tomography
- Biological effect of ionizing radiation / dosimetry
- Imaging techniques in nuclear medicinal diagnosis
- Imaging techniques: ultrasound
- Imaging techniques: thermography and impedance tomography
- Imaging techniques: electrical sources, optical tomography, endoscopy
- Imaging techniques: MR tomography
- Imaging techniques: molecular imaging

Finally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.

Examination achievement

see module details

Course achievement

see module details

Literature

Actual copies of the slides will be delivered accompanying to the lectures.
Literature:

German 1. Dössel, Olaf: Bildgebende Verfahren in der Medizin. Berlin, Heidelberg: Springer-Verlag, 2000 2. Schmidt, Robert F., Lang, Florian, Thews, Gerhard (Hrsg.): Physiologie des Menschen, 29. Auflage. Heidelberg: Springer Medizin Verlag, 2005 **English** 1. Bronzino, Joseph D. (Hrsg.): The Biomedical Engineering Handbook, Volume 1 (and 2), Second Edition. Boca Raton: CRC Press 2000 / Heidelberg: Springer-Verlag, 2000 2. Enderle, John, Blanchard, Susan, Bronzino, Joseph (Hrsg.): Introduction to Biomedical Engineering, Second Edition. Burlington, San Diego, London, Elsevier, 2005
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Biomedizinische Messtechnik II / Biomedical Instrumentation II	11LE50MO-5302 PO 2021
Veranstaltung	
Biomedizinische Messtechnik II / Biomedical Instrumentation II - Übung	
Event type	Number
Übung	11LE50Ü-5302
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	Number of module
Biomedizinische Messtechnik - Praktikum / Biomedical Instrumentation - Laboratory	11LE50MO-5304 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
Successful completion of "Biomedical Instrumentation I" is a prerequisite for attending this module.
Recommended requirement
Grundkenntnisse in Mathematik und Naturwissenschaften

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Biomedizinische Messtechnik - Praktikum / Biomedical Instrumentation - Laboratory	Praktikum		3.0	4.0	90 hours

Qualification
The aim of the module is to perform the recording of bioelectrical signals by oneself, applying the theoretical knowledge of recording signals and suppressing disturbances and artifacts and supplementing it with practical skills. The module teaches microsystems engineering students how to handle surface electrodes, develop simple electronic circuits and the basics of digital signal processing of bioelectric signals, as well as how to use software to create automatic signal recording routines.
Examination achievement
Written documentation
Course achievement
The "Studienleistung" is considered passed if 50% of maximum points will be achieved in each of the four tests that are written with prior notice. For the lab sessions, attendance is mandatory. In case of illness an additional lab session is offered. It is also possible to ask for auxiliary dates and to have access to the chair’s labs outside the lab sessions.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Biomedizinische Messtechnik - Praktikum / Biomedical Instrumentation - Laboratory	11LE50MO-5304 PO 2021
Veranstaltung	
Biomedizinische Messtechnik - Praktikum / Biomedical Instrumentation - Laboratory	
Event type	Number
Praktikum	11LE50P-5304
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	60 hours
Independent study	30 hours
Hours of week	4.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	
Group size	15

Contents
The practical exercises are performed in small groups of maximum three persons. In the first part, diagnostic procedures (e.g. blood pressure measurement, electrocardiogram, determination of motor nerve conduction velocity, electro-myogram) are learned and characteristic quantities are extracted from the signals. In the second part, students independently design and develop an electronic amplifier circuit to record muscle signals and a user interface to graphically display the signals and control a screen pointer using the recorded muscle signals. This development of a simple human-computer interface is finally tested under real-time conditions.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
Successful completion of "Biomedical Instrumentation I" is a prerequisite for attending this module.
Recommended requirement
Basic knowledge in mathematics and sciences.

↑

Name of module	Number of module
BioMEMS	11LE50MO-5403 PO 2021
Responsible	
Organizer	
Institut für Mikrosystemtechnik Elektr. Messt. u. Eingebettete Sys.	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
none
Recommended requirement
Kenntnisse aus dem Modul "Sensors" oder "Sensorik/Aktorik"

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
BioMEMS - Vorlesung	Vorlesung		3.0	2.0	90 hours

Qualification
After this lecture, the students will overview the application of MEMS in biology and medicine. They will know the recent microfabrication technologies for biomedical applications as well as the basics of cell biology and biochemistry. The attendees of this lecture will think about the social impact of engineering. Most importantly, they will understand the connections between biology, medicine, and engineering. Finally, the students can apply this understanding to future topics in this field.
Examination achievement
Written examination (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
BioMEMS	11LE50MO-5403 PO 2021
Veranstaltung	
BioMEMS - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5403
Organizer	
Institut für Mikrosystemtechnik Sensoren	

ECTS-Points	3.0
Workload	90 hours
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Content 1. Introduction 2. Biochemistry and cells 3. Cell culture monitoring 4. Organ-on-chip (OOC) systems 5. Cell mechanics 6. Single cell analysis 7. DNA, RNA and protein analytics on chip 8. Implantable devices, in vivo sensors 9. Wearables 10.Summary
Examination achievement
see module details
Course achievement
none
Compulsory requirement
none
Recommended requirement
Knowledge from the module "Sensors" or "Sensors/Acuators"

Teaching method
■ Lecture (recorded) ■ Q&A live sessions ■ Surveys (ethics, social impact) ■ Design task (cooperative, in a live session)

↑

Name of module	**Number of module**
Biophysics of cardiac function and signals	11LE50MO-5324 PO 2021
Responsible	
Prof. Dr. Jens Timmer Dr. Viviane Timmermann	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
Basic interest in biology and computational modeling Knowledge in Python (or equivalent) is beneficial

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Biophysics of cardiac function and signals	Vorlesung		6.0	2.0	180 hours
Biophysics of cardiac function and signals - praktische Übung	Übung			2.0	

Qualification
The basic concept of this lecture is to examine a biological system, analyze it and define mathematical equations in order to describe the system. In this lecture, the heart is used as this system. The students learn the electrical and mechanical function of the heart and its modeling. Additionally, the bioelectrical signals that are generated in the human body are described and how these signals can be measured, interpreted and processed. The content is explained both on the biological level and based on mathematical modelling. Aligned to the lecture is the exercise in which students learn to implement and use these models, get a practical introduction to medical image processing and perform signal processing using python.
Examination achievement
oral examination (30 minutes)
Course achievement
Regelmäßige Teilnahme an der Lehrveranstaltung gemäß §13 (2) der Rahmenprüfungsordnung Master of Science/regular participation according to §13 (2) of the framework examination regulations M.Sc.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Biophysics of cardiac function and signals	11LE50MO-5324 PO 2021
Veranstaltung	
Biophysics of cardiac function and signals	
Event type	Number
Vorlesung	11LE50V-5324

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
• Cell membrane and ion channels • Cellular electrophysiology • Conduction of action potentials • Cardiac contraction and electromechanical interactions • Optogenetics in cardiac cells • Image processing and numerical field calculation in the body • Measurement of bioelectrical signals • Electrocardiography • Imaging of bioelectrical sources (ECG imaging) • Biosignal processing
Examination achievement
see module details
Course achievement
see module details
Literature
Lecture slides (further literature is included in the slides)
Compulsory requirement
none
Recommended requirement
Knowledge in Python (or equivalent) is beneficial Basic interest in biology and computational modeling

↑

Name of module	**Number of module**
Biophysics of cardiac function and signals	11LE50MO-5324 PO 2021
Veranstaltung	
Biophysics of cardiac function and signals - praktische Übung	
Event type	Number
Übung	11LE50prÜ-5324

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
none
Literature
Python implementation of • Hodgkin-Huxley model • Ion channel model adjustment to measurement data • Simulation of cardiac electrophysiology using openCARP • Image processing • ECG signal processing
Compulsory requirement
none

↑

Name of module	**Number of module**
Biotechnologie für Ingenieurinnen und Ingenieure I - Praktikum: Mikro- und Molekularbiologie	11LE50MO-5373 PO 2021
Responsible	
Prof. Dr. Felix von Stetten	
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden | hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
keine | none
Recommended requirement
Participation in the examination of "Biotechnology for Engineers I - Lecture"

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Biotechnologie für Ingenieurinnen und Ingenieure I - Praktikum: Mikro- und Molekularbiologie	Praktikum		3.0	2.0	

Qualification
Successful candidates are able to independently apply basic laboratory methods in the field of micro- and molecular biology, as well as to perform, report, and discuss their laboratory experiments.
Examination achievement
▪ Protokoll/report on the lab excersises (50%) ▪ mündlicher Vortrag / oral presentation with a duration of 30 minutes (50%)

Course achievement
Durchführung von 10 Versuchen / carrying out of 10 experiments: 1. Presentation of Protocol 2. Pipetting 3. Buffer 4. Microbiological culture 5. Manual DNA-extraction 6. LabDisk DNA-extraction 7. Manual Real-time PCR 8. GeneSlice Real-time PCR 9. Gelelectrophoresis 10. Immunoassay
Usability
As compulsory elective in ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Biomedical Engineering ■ M.Sc. Microsystems Engineering in Microsystems Engineering Concentrations Area: Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik

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Name of module	**Number of module**
Biotechnologie für Ingenieurinnen und Ingenieure I - Praktikum: Mikro- und Molekularbiologie	11LE50MO-5373 PO 2021
Veranstaltung	
Biotechnologie für Ingenieurinnen und Ingenieure I - Praktikum: Mikro- und Molekularbiologie	
Event type	Number
Praktikum	11LE50Pr-5373 PO 2021
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	

ECTS-Points	3.0
Hours of week	2.0
Recommended semester	2
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
- Preparation of nutrient media - Bacterial culture - Determination of bacterial count - DNA extraction from bacteria - DNA quantitation by real-time PCR - Detection of bacteria by Immunoassay - Assay automation by lab-on-a-chip technology 1) The lab course will take place at the end of each semester. 2) Block course of four days 3) Students are required to study the script before the lab course starts. 4) Students are required to prepare a 10 minutes talk about one selected laboratory method 5) Students are required to report the 10 experiments performed as individual laboratory record
Examination achievement
siehe Modulebene
Course achievement
siehe Modulebene
Literature
Script "Lab course Biotechnology for Engineers I" - Felix von Stetten et al. (will be provided on ILIAS)
Compulsory requirement
none
Recommended requirement
Participation in the examination of "Biotechnology for Engineers I - Lecture"

↑

Name of module	Number of module
Digital Health (DH)	11LE50MO-1160 PO 2021
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Digital Health (DH)	Vorlesung		6.0	2.0	180 hours
Digital Health (DH)	Übung			2.0	

Qualification
* Understand the data sources and modalities in digital medicine and the processes of data integration in clinical information systems and DGAs * Understand the German DGA regulation and issues relating to data privacy * Apply ubiquitous technology (ambient, mobile, wearable, implantable) for digital health * Apply context recognition and personalisation methods to qualify ubiquitous system data * Apply data-based privacy preserving techniques (obfuscation) * Design and implement digital biomarkers based on multimodal data * Design and apply digital health twins and clinical data modelling * Design medical decision support systems based on multimodal data
Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) If there are too many students for a reasonably organized oral exam, it will be held as a written exam instead, announced well in advance.

Course achievement
written composition Reports on exercises to be submitted
Literature
Up-to-date literature recommendations are provided during the lectures.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science **OR** in Microsystems Engineering Concentrations Area Biomedical Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

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Name of module	**Number of module**
Digital Health (DH)	11LE50MO-1160 PO 2021
Veranstaltung	
Digital Health (DH)	
Event type	Number
Vorlesung	11LE13V-1160_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	6.0
Workload	180 hours
Attendance	32 hours
Independent study	116 hours
Hours of week	2.0
Recommended semester	3
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Digital health is a branch of digital medicine that integrates and leverages multisource and multimodal data for medical knowledge extraction and decision support across a wide range of preventive, diagnostic, and therapeutic applications. The course starts by introducing the basic properties of medically relevant data sources and their different modalities. The course introduces the medical benefits of using ubiquitous technologies for data collection, in particular, between hospital visits. The process of medical data integration in clinical information systems and in digital health applications ("Digitale Gesundheitsanwendungen", DGA) is discussed. The German DGA regulations and their consequences are introduced, in particular relating to digital health application qualification and data privacy. Privacy preserving techniques are discussed and applied. Subsequently, data interpretation in telemedicine and digital biomarker design are analysed regarding context recognition and personalisation methods and algorithms. Decision support systems are dissected regarding their components and data analysis algorithms. Finally, the concept, realisation, and application of digital health twins in medicine is developed. The exercises will include practical experiments and implementation tasks, e.g. smartphone apps, 3D digital twin modelling, and data analysis for decision support.
Examination achievement
see module level
Course achievement
see module level
Literature
Up-to-date literature recommendations are provided during the lectures.
Compulsory requirement
None

Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

↑

Name of module	**Number of module**
Digital Health (DH)	11LE50MO-1160 PO 2021
Veranstaltung	
Digital Health (DH)	
Event type	Number
Übung	11LE13Ü-1160_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	
Attendance	32 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Students will investigate concrete data science methods related to medical data, including context recognition, data interpretation and abstraction.
Examination achievement
see module level
Course achievement
see module level
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Embedded Computing Entrepreneurship (2ES)	Vorlesung		6.0	1.0	180 Stunden / Hours
Embedded Computing Entrepreneurship (2ES)	Seminar			1.0	
Embedded Computing Entrepreneurship (2ES)	Übung			2.0	

Qualification
* Conceptualise and design embedded sensor systems along a specific application. * Develop and demonstrate key components of embedded sensor systems, including signal and pattern analysis and recognition algorithms. * Develop a basic market analysis and business plan. * Implement an agile development process.
Examination achievement
Presentation followed by an oral examination (10 minutes per person, total duration depends on group size)

Course achievement
Regular attendance of the course (seminar and exercise) according to §13 (2) of the General Examination Regulations for the Bachelor of Science/Master of Science, as otherwise the required group work and scientific discussion is not possible. Further elements of the course work are the creation of demonstrators or software as well as a written elaboration/protocol.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Circuits and Systems **OR** Elective Courses in Computer Science ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung **|** Specialization Courses Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Veranstaltung	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
Vorlesung	11LE13V-1404_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	16 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
The course combines technical and business-related lectures on embedded sensor systems with a practical system development project using agile development methods. Students will organise in groups and define together with their advisor(s) goals for the technical development, market analysis, etc. Student groups can enter their projects for an award of the VDE.
Examination achievement
see module details
Course achievement
see module details
Literature
Relevant literature will be provided during the lectures and consultations.
Compulsory requirement
None
Recommended requirement
Basic pattern recognition methods; basic programming skills

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Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Veranstaltung	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
Seminar	11LE13S-1404_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	
Attendance	16 Stunden / Hours
Hours of week	1.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Veranstaltung	
Embedded Computing Entrepreneurship (2ES)	
Event type	Number
Übung	11LE13Ü-1404_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Name of Non-graded work	
Exam type	Number
Responsible	
Faculty	

Exam form	
Grading	
Compulsory	

↑

Name of module	Number of module
Embedded Computing Entrepreneurship (2ES)	11LE13MO-1404 MST/MSE PO 2021
Name of Examination	
Exam type	Number
Responsible	
Faculty	

Exam form	
Grading	
Recommended semester	2
Compulsory	

↑

Name of module	**Number of module**
Ethische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology	11LE50MO-5320 PO 2021
Responsible	
Prof. Dr. Ulrich Egert	
Organizer	
Institut für Mikrosystemtechnik Biomikrotechnik	
Faculty	
Technische Fakultät	

ECTS-Points	3
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine
Recommended requirement
Interesse an interdisziplinärer Aufbereitung aktueller Fragestellungen

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Ethische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology - Seminar	Seminar		3.0	2.0	90 Stunden

Qualification
Studierende der Philosophie und Studierende der Neurobiologie und der Ingenieurwissenschaften erarbeiten in diesem Seminar gemeinsam ethische und philosophische Perspektiven der aktuellen Eingriffsmöglichkeiten in das Gehirn und der derzeit entwickelten und in naher Zukunft entwickelbaren Mensch-Maschine-Komplexe, um auf dieser Grundlage die Herausforderungen für unser personales Selbstverständnis und unsere ethischen Kriterien für die Grenzen solcher Eingriffe zu diskutieren. Dabei soll versucht werden, philosophische Ansätze zum Verhältnis von Person sein und neurobiologischer „Determinierung“ als zentrale Aspekte in der ethischen Theoriebildung mit den empirischen und interagierenden Zugängen der Neurowissenschaften in einen konstruktiven und kontroversen Dialog gebracht werden.
Examination achievement
Mündliche Abschlussprüfung (30 Minuten)
Course achievement
keine

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Ethische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology	11LE50MO-5320 PO 2021
Veranstaltung	
Ethische Aspekte der Neurotechnologie / Ethical Aspects of Neurotechnology - Seminar	
Event type	Number
Seminar	11LE50S-5320
Organizer	
Institut für Mikrosystemtechnik Biomikrotechnik	

ECTS-Points	3.0
Workload	90 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Interdisziplinäres Seminar zu ethischen und philosophischen Aspekten der Neurotechnologie.

Folgende Themenbereiche werden jeweils unter ethischen, neurowissenschaftlichen bzw. ingenieurwissenschaftlichen Gesichtspunkten bearbeitet:

1. Ethik der Neurowissenschaften als aktuelles Gebiet der Philosophie
2. Identität, Person und Persönlichkeit als Grundbegriffe der Ethik der Neurowissenschaften
3. Spezifische philosophische und ethische Aspekte folgender Anwendungsfelder:
   - Invasive und nicht-invasive Gehirn-Maschine-Schnittstellen
   - Neuroimaging- Emotionale Integration neuronaler Prothesen
   - Tiefe Hirnstimulation
   - Optogenetische Interaktion
   - Neuro-Enhancement
   - Zukunftstechnologien und deren Einsatz

Examination achievement

siehe Modulebene

Course achievement

keine

Compulsory requirement

keine

Recommended requirement

Interesse an interdisziplinärer Aufbereitung aktueller Fragestellungen

↑

Name of module	**Number of module**
Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation	11LE50MO-5306 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation - Vorlesung	Vorlesung		3.0	2.0	90 hours

Qualification
The aim of the module is to teach the biological-medical and physicochemical-technical fundamentals in the electrostimulation of nerves and muscles, which are necessary for an engineer to understand the biological processes and to design aids and procedures in applications in the field of neuroprosthetics and neuromodulation. The module teaches students the theoretical background of mechanisms of action and damage of electrical stimulation in the peripheral and central nervous systems, as well as the electrochemical processes to be considered at neuro-engineering interfaces.
Examination achievement
Oral exam (30 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation	11LE50MO-5306 PO 2021
Veranstaltung	
Grundlagen der Elektrostimulation / Fundamentals of electrical stimulation - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5306

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The course introduces the medical and biological as well as the physicochemical and technical aspects of electrical stimulation. In detail, students get familiar with the following topics: Overview of the history of electrical stimulation Anatomy and physiology of nerve and muscle Description of nerve excitation Electrical fields and electrochemical processes at electrodes Electrode designs and applications Charakteristic parameters during technical excitation of nerves Methods for selective stimulation Effects of chronic electrical stimulation Limits of safe electrical stimulation Systems theory aspects of control of neural prostheses Simulation of nerve excitation Stimulator design Overview of stimulation parameters in clinical applicationsFinally, the content of the course and the learning targets will be summarized together with the students to facilitate the preparation of the examination.
Examination achievement
see module details
Course achievement
None
Literature
A script will be provided to accompany the lecture and will be updated regularly. Further reading material: ■ Horch, K.W., Dhillon, G.S. (Hrsg.): Neuroprosthetics – Theory and Practice. (Series on Bioengineering & Biomedical Engineering – Vol. 2) ■ River Edge: World Scientific Computing, 2004

Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Introduction to data driven life sciences	11LE13MO-1335 PO 2021
Responsible	
Prof. Dr. Rolf Backofen	
Organizer	
Institut für Informatik Bioinformatik	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Introduction to data driven life sciences	Vorlesung		6.0	2.0	180 hours
Introduction to data driven life sciences	Übung			2.0	

Qualification
- The students have a basic knowledge and understanding about origin and content of life science high-throughput data - They know methods and tools for the analysis of such data, can compare it to different data, and have knowledge about visualization - They are able to analyse small data sets and apply their gained knowledge
Examination achievement
Written exam (120 minutes).
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Introduction to data driven life sciences	11LE13MO-1335 PO 2021
Veranstaltung	
Introduction to data driven life sciences	
Event type	Number
Vorlesung	11LE13V-1335
Organizer	
Institut für Informatik Bioinformatik	

ECTS-Points	6.0
Workload	180 hours
Attendance	30 hours
Independent study	120 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

In biological and medical research big data analysis is urgently needed for understandig the information that is encoded in the molecules of life. Many diseases, such as cancer, are caused by aberrations in those molecules. In this lecture you will learn the theoretical biological and bioinformatics background and techniques for generation and analysis of high-throughput data in life sciences.

Examination achievement

see module details

Course achievement

see module details

Compulsory requirement

None

Recommended requirement

None

Recommendation

Important note for M.Sc. Computer Science:
This module is available as both
- a specialization lecture in Computer Science (with a graded assessment / Prüfungsleistung)
- as a course in the application area Applied Bioinformatics (as pass/fail course / Studienleistung)

Take care during the booking process, as that will define the category in which the course is considered.
You can't change the category afterwards!
So, you can't change it from PL to SL or vice versa.

↑

Name of module	**Number of module**
Introduction to data driven life sciences	11LE13MO-1335 PO 2021
Veranstaltung	
Introduction to data driven life sciences	
Event type	Number
Übung	11LE13Ü-1335
Organizer	
Institut für Informatik Bioinformatik	

ECTS-Points	
Attendance	30 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
To apply the gained knowledge from the lecture, exercises to various topics of high-throughput data analysis are offered. Moreover, we will get to know the workflow management framework Galaxy which is an open source tool for life science data analysis.
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Introduction to physiological control systems	11LE50MO-5258 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Introduction to physiological control systems	Vorlesung		3.0	1.0	90 hours
Introduction to physiological control systems	Übung			1.0	

Qualification
This course will introduce students in engineering and non-engineering fields to the modeling and control of physiological processes. A brief introduction to signals, systems and control theory is provided at the beginning. Several physiological process are then addressed from a control system perspective, discussing state-of-the-art literature. The main goal of this course is to provide a general overview of how control system theory can be applied to understand, modeling and control physiological processes.
Examination achievement
Written examination (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Introduction to physiological control systems	11LE50MO-5258 PO 2021
Veranstaltung	
Introduction to physiological control systems	
Event type	Number
Vorlesung	11LE50V-5258
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	1.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
1. Introduction and course overview. 2. Review of signals, systems, and control theory. 3. Positive and negative feedback in physiology. 4. Blood pressure control. 5. Balance control during quiet standing. 6. Complex dynamics of heart rate variability. 7. Feedback and feedforward limb control during reach-to-pinch task. 8. Summary.
Examination achievement
see module details
Course achievement
None
Literature
1. M. Khoo. Physiological control systems: analysis, simulation, and estimation. IEEE Series in Biomedical Engineering, 1999, NY. 2. A. Guyton and J. Hall, Textbook of Medical Physiology, Elsevier, 2006. 3. Current scientific literature.
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Introduction to physiological control systems	11LE50MO-5258 PO 2021
Veranstaltung	
Introduction to physiological control systems	
Event type	Number
Übung	11LE50Ü-5258
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
See module details
Course achievement
None
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	Number of module
Machine Learning	11LE13MO-1153 PO 2021
Responsible	
Prof. Dr. Joschka Bödecker Prof. Dr. Frank Roman Hutter	
Organizer	
Institut für Informatik Neurorobotik Institut für Informatik Maschinelles Lernen	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden | hours
Recommended semester	1
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine | none
Recommended requirement
We have to rely on a solid background in basic math, specifically linear algebra (an eigenvalue decomposition, matrix operations, covariance matrices etc. should be very familiar concepts), calculus and probability theory. We use the Python programming language for most of our assigments. If you do not yet have Python experience, you must ramp up at least basic knowledge thereof. We recommend basic knowledge of optimization and of the scikit-learn Python library.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Machine Learning	Vorlesung		6.0	3.0	180 Stunden | hours
Machine Learning	Übung			1.0	

Qualification
This course provides you with a good theoretical understanding and practical experience about the basic concepts of machine learning. You shall be enabled to implement a number of basic algorithms, understand advantages and drawbacks of single methods and know typical application domains thereof. Furthermore, you should be able to use (Python) software libraries in order to work on novel data analysis problems.

The course will prepare you to dive deeper into advanced methods of ML, e.g. deep learning, recurrent networks, reinforcement learning, hyperparameter optimization, and into specific application domains such as image analysis, brain signal analysis, robot learning, bioinformatics etc., for which specialized courses are available.
Examination achievement
Ususally a written exam (duration of 90 to 180 minutes) If the number of participants is small, an oral examination (with a duration of 35 minutes) may be held instead. The students will be informed in good time.
Course achievement
To prepare for the exam, there can be a mock exam (written or oral).
Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021) Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Weiterführende Vorlesung | Advanced Lectures ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science ■ Students of the M.Sc. programs Microsystems Engg. and Mikrosystemtechnik (PO 2021) can select this module in the concentration area Biomedical Engineering (Biomedizinische Technik). Teil der Spezialisierung Künstliche Intelligenz im Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering| Part of the specialization Artificial Intelligence in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering

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Name of module	**Number of module**
Machine Learning	11LE13MO-1153 PO 2021
Veranstaltung	
Machine Learning	
Event type	Number
Vorlesung	11LE13V-1153
Organizer	
Institut für Informatik Maschinelles Lernen	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	45 Stunden | hours
Independent study	120 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Applications / typical problems dealt with by machine learning
- basic data analysis pipeline (from data recording to output shaping)
- software libraries
- linear methods (e.g. LDA, logistic regression, ICA, PCA, OLSR) for dimensionality reduction, classification, regression and blind source separation
- non-linear methods (e.g. support vector machines, kernel PCA, decision trees / random forests, neural networks) for classification and regression
- unsupervised clustering (e.g. k-means, DBSCAN)
- algorithm independent principles in machine learning (z.b. bias-variance trade-off, model complexity, regularization, validation strategies, interpretation of trained machine learning models, basic optimization approaches, feature selection, data visualization)

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

Duda, Hart and Stork: Pattern Classification
Christopher Bishop: Pattern Recognition and Machine Learning
Hastie, Tibshirani and Friedman: The Elements of Statistical Learning
Mitchell: Machine Learning
Murphy: Machine Learning – a Probabilistic Perspective
Criminisi et. al: Decision Forests for Computer Vision and Medical Image Analysis
Schölkopf & Smola: Learning with Kernels

Goodfellow, Bengio and Courville: Deep Learning Michael Nielsen: Neural Networks and Deep Learning In addition, literature for every section of the course is announced during these sections.
Compulsory requirement
keine | none
Recommended requirement
We have to rely on a solid background in basic math, specifically linear algebra (an eigenvalue decomposition, matrix operations, covariance matrices etc. should be very familiar concepts), calculus and probability theory. We use the Python programming language for most of our assigments. If you do not yet have Python experience, you must ramp up at least basic knowledge thereof. We recommend basic knowledge of optimization and of the scikit-learn Python library.
Teaching method
For in-class lectures: Despite the large lecture rooms, a teacher-centered style shall be enriched as much as possible by measures like: ■ interactive question and answer rounds ■ discussions in sub-groups, reporting to the large group ■ cross-teaching ■ problem-oriented teaching e.g. via data analysis competition ■ repetition of important concepts in slightly altered contexts. **For virtual lectures:** ■ flipped classroom teaching with videos provided ■ Q&A sessions to discuss the videos' content ■ Cross-teaching via Ilias forum ■ problem-oriented teaching e.g. via data analysis competition ■ repetition of important concepts in slightly altered contexts.

↑

Name of module	**Number of module**
Machine Learning	11LE13MO-1153 PO 2021
Veranstaltung	
Machine Learning	
Event type	Number
Übung	11LE13Ü-1153
Organizer	
Institut für Informatik Maschinelles Lernen	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercises are intended to give students a better understanding of the most important techniques they learn during lectures. They are expected to implement some selected methods to gain experience in practical applications.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science	11LE13MO-1112 PO 2021
Responsible	
Prof. Dr. Rolf Backofen	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	in jedem Semester

Compulsory requirement
none
Recommended requirement
Knowledge in Machine Learning and Bioinformatics, basic knowledge in Molecular biology

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science	Vorlesung		6.0	2.0	180 Stunden | hours
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science	Übung			2.0	

Qualification
Students learn to consider machine learning applications in life sciences from different perspectives. They understand the biological point of view in regards to problems in the domains of genomics, proteomics, systems biology and biological literature information mining. They also have an understanding of different questions from the machine learning point of view, such as underlying assumptions in predictive models, the quality assessment problem, the design choices for supervised and unsupervised models.
Examination achievement
Klausur (i.d.R. 90 bis 180 Minuten) | Written exam (usually 90 to 180 minutes) Wenn die Teilnehmerzahl gering ist (< 20), kann stattdessen eine mündliche Prüfung durchgeführt werden. Die Studierenden werden rechtzeitig informiert. | If the number of participants is small (< 20), an oral examination may be held instead. The students will be informed in good time.

Course achievement
keine | none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung | Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science Students of the M.Sc. programmes Microsystems Engg. and Mikrosystemtechnik (PO 2021) can select this module in the concentration area Biomedical Engineering (Biomedizinische Technik).

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Name of module	Number of module
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science	11LE13MO-1112 PO 2021
Veranstaltung	
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science	
Event type	Number
Vorlesung	11LE13V-1112
Organizer	
Institut für Informatik Bioinformatik	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	30 Stunden
Independent study	120 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The course will maintain a double perspective: from the biological point of view we consider problems in the domains of genomics, proteomics, systems biology and biological literature information mining; from the machine learning point of view, we consider questions such as the underlying assumptions in predictive models, the quality assessment problem, the design choices for supervised and unsupervised models.

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

The course material is based on influential publications both in the Machine Learning and/or Bioinformatics literature:

- P Baldi, S Brunak, Y Chauvin, C.A.F Andersen, H Nielsen, Assessing the accuracy of prediction algorithms for classication: an overview, Bioinformatics 2000
- T Fawcett, An introduction to ROC analysis, Pattern Recognition Letters 2006
- T Dietterich, Approximate statistical tests for comparing supervised classication learning algorithms, Neural Computation 1998
- D Jiang, C Tang, A Zhang, Cluster analysis for gene expression data: A survey, IEEE transactions on knowledge and data engineering 2004
- S.C Madeira, A.L Oliveira, Biclustering algorithms for biological data analysis: a survey, IEEE Transactions on computational Biology and Bioinformatics 2004
- A Krause, J Stoye, Large scale hierarchical clustering of protein sequences, BMC bioinformatics 2005

- P Baldi, G Pollastri, The principled design of large-scale recursive neural network architectures-dag-rnns and the protein structure prediction problem, The Journal of Machine Learning Research 2003
- C Leslie, E Eskin, W Noble, The spectrum kernel: A string kernel for SVM protein classication,Pacic Symposium on Biocomputing 2002
- X.W. Chen, Prediction of protein-protein interactions using random decision forest framework, Bioinformatics 2005

Compulsory requirement
none
Recommended requirement
Knowledge in Machine Learning and Bioinformatics, basic knowledge in Molecular biology

↑

Name of module	**Number of module**
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science	11LE13MO-1112 PO 2021
Veranstaltung	
Maschinelles Lernen in den Lebenswissenschaften / Machine Learning in Life Science	
Event type	Number
Übung	11LE13Ü-1112
Organizer	
Institut für Informatik Bioinformatik	

ECTS-Points	
Attendance	30 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
In the exercises, students will learn through example scenarios to apply the principles and methods from the lectures.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement

↑

Name of module	**Number of module**
Messung und Auswertung elektrophysiologischer Signale	11LE50MO-5325 PO 2021
Responsible	
PD Dr. Matthias Dümpelmann	
Organizer	
Institut für Mikrosystemtechnik	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
Knowledge in digital signal processing Programming skills in languages like Python

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Messung und Auswertung elektrophysiologischer Signale	Praktikum		3.0	2.0	

Qualification
1. Components of equipment for electrophysiological measurements 2. Experience in performing measurements of electrophysiological signals 3. Knowledge about potential noise sources and strategies for their mitigation 4. Experience in cognitive experiments in parallel to electrophysiological measurements 5. Knowledge in methods for signal analysis in time and frequency domain.

Examination achievement
Protokoll / report Benotete Protokolle: Neben der Durchführung von Versuchen werden aufgenommene Signale und Signale aus Datenbanken von den Studierenden analysiert (z.B. mit Hilfe von Python / Erstellung von Software). Graded protocols: In addition to conducting experiments, recorded signals and signals from databases are analyzed by the students (e.g. using Python / creating software).
Course achievement
Durchführung von Versuchen / Carrying out of experiments

↑

Name of module	**Number of module**
Messung und Auswertung elektrophysiologischer Signale	11LE50MO-5325 PO 2021
Veranstaltung	
Messung und Auswertung elektrophysiologischer Signale	
Event type	Number
Praktikum	11LE50P-5325 PO 2021
Organizer	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
1. Components of equipment for electrophysiological measurements 2. Measurement of the electrocardiogram (ECG) 3. Measurement of the photoplethysmogram as a proxy of the ECG 4. Measurement of the electroencephalogram (EEG) 5. Signal analysis of the ECG and EEG in time and frequency domain 6. Components of systems for cognitive experiments 7. Realization of a cognitive experiments while measuring the electroencephalogram 8. EEG signal analysis of cognitive experiments
Examination achievement
see module details
Course achievement
see module details
Literature
In Englisch: Cohen: Analyzing Neural Time Series Data: Theory and Practice Smith: The scientist and engineer's guide to digital signal processing Niedermeyer, Lopes da Silva: Electroencephalography: basic principles, clinical applictions, and related fields In Deutsch: Openheim, Schafer: Zeitdiskrete Signalverarbeitung BErnhard, Brensing, Witte: Biosignalverarbeitung: Grundlagen und Anwendungen mit MATLAB

Compulsory requirement
None
Recommended requirement
Knowledge in digital signal processing Programming skills in languages like Python

↑

Name of module	**Number of module**
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	11LE50MO-5263 PO 2021
Responsible	
Prof. Dr.-Ing. Roland Zengerle	
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
Basics in microfluidics, e.g. "Microfluidics I"

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	Vorlesung		6.0	2.0	180 hours
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	Übung			2.0	

Qualification
Qualified microfluidic engineer with sound knowledge on microfluidic Design, manufacturing of microfluidic cartridges, and the use of microfluidic technologies in clinical settings.
Examination achievement
Ususally a written exam (duration of 90 to 180 minutes) If the number of participants is small, an oral examination (with a duration of 35 minutes) may be held instead. The students will be informed in good time.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	11LE50MO-5263 PO 2021
Veranstaltung	
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	
Event type	Number
Vorlesung	11LE50V-5263
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Content: This lecture teaches the use of microfluidic technologies for automation of biochemical analyses. Fields of application are the detection of pathogens, the diagnosis and therapy accompanied monitoring of tumor diseases as well as water analysis. In a first section, the complete design process from initial requirements and project specifications to simulation-based design, manufacturing of functional models and testing will be addressed. The creation of flow drafts, the simulation of microfluidic networks and CAD design will be taught in an accompanying tutorial. In following lectures, product development will be examined. This includes the scalable manufacturing of disposable test cartridges, the determination of usability as well as questions of licensing. In summary, the lecture covers the development process from initial idea to product. In the second part of the tutorial, the students will work on an exemplary project.
Examination achievement
see module details
Course achievement
none
Compulsory requirement
none
Recommended requirement
Basics of microfluidics, e.g. Microfluidics I lecture

↑

Name of module	**Number of module**
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	11LE50MO-5263 PO 2021
Veranstaltung	
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	
Event type	Number
Übung	11LE50Ü-5263
Organizer	
Technische Fakultät Institut für Mikrosystemtechnik Anwendungsentwicklung	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
none
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	Number of module
Nanobiotechnologie / Nanobiotechnology	11LE50MO-5308 PO 2021
Responsible	
Prof. Dr. Oliver Ambacher	
Organizer	
Inst. f. Nachh. Technische Systeme Prof. f. Leistungselektronik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine
Recommended requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Nanobiotechnologie / Nanobiotechnology	Vorlesung		3.0	2.0	90 Stunden

Qualification
Die Studierenden werden in die Lage versetzt, die Funktionsweise von organischen Mikro- und Nanosystemen zu verstehen. Hierzu gehören z.B. Haarzellen, Motorproteine, organische Nanomotoren und Ionenkanäle. Die Studierenden besitzen Fachkompetenz in der Beschreibung und Analyse von organischen Nanostrukturen, die für die Funktion kleinster biologischer Organismen von entscheidender Bedeutung sind. Ihre Fachkompetenz erstreckt sich bis zur Kombination von organischen und anorganischen Mikro- und Nanosystemen z.B. zur Realisierung kleinster Antriebssysteme. Students will be able to understand the functioning of organic micro- and nanosystems. These include, for example, hair cells, motor proteins, organic nanomotors and ion channels. Students will have expertise in the description and analysis of organic nanostructures that are critical to the function of minute biological organisms. Their expertise extends to the combination of organic and inorganic micro- and nanosystems, e.g., for the realization of very small drive systems.
Examination achievement
Mündliche Abschlussprüfung mit einer Dauer von 30 Minuten

Course achievement
keine
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Nanobiotechnologie / Nanobiotechnology	11LE50MO-5308 PO 2021
Veranstaltung	
Nanobiotechnologie / Nanobiotechnology	
Event type	Number
Vorlesung	11LE50V-5308
Organizer	
Inst. f. Nachh. Technische Systeme Prof. f. Leistungselektronik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26 Stunden
Independent study	64 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Zu den Themen der Nanobiotechnologie gehört die Diskussion von organischen Nanosystemen in der menschlichen Wahrnehmung, die Erklärung des Handlings und Charakterisierens von Proteinen und Viren, die Untersuchung elektronischer und optischer Eigenschaften von einzelnen Molekülen genauso wie die Technologie zur Herstellung von Sensoren für kleinste Flüssigkeitsmengen. An der Schnittstelle zwischen der Mikro- und Nanowelt, der Schnittstelle auch zwischen belebter und unbelebter Materie, werden moderne Charakterisierungsverfahren (z.B. Elektronenmikroskopie, Kraftmikroskopie) nötig, um von physikalischen oder chemischen Eigenschaften der organischen Moleküle eine Brücke zum Verständnis der Funktion von Aminosäuren, Proteinen und Zellen zu schlagen. Diese Methoden und ihre Anwendung auf biologisch relevante Systeme werden ebenso erklärt wie die Technologie zur Herstellung von künstlichen Mikro- und Nanostrukturen zur sensorischen Kopplung an biologische Organismen.

Examination achievement

siehe Modulebene

Course achievement

keine

Literature

- Biochemie, J.M. Berg, J.L. Tymoczko, L. Stryer, Spektrum Akademischer Verlag, Heidelberg 2003
- Physiologie des Menschen, R.F. Schmidt, F. Lang, G. Thews, Springer Medizin Verlag Heidelberg 2005

Compulsory requirement

keine

Recommended requirement

keine

↑

Name of module	**Number of module**
Neurophysiologie - Praktikum / Neurophysiology - Laboratory	11LE50MO-5316 PO 2021
Responsible	
Prof. Dr. Ulrich Hofmann	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
Prerequisite to become eligible for this course is the participation in the exercises in "Implant manufacturing technologies“ or participation in the seminar „Neuroprosthetics“ in the previous winter semester.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Neurophysiologie - Praktikum / Neurophysiology - Laboratory	Praktikum		3.0	4.0	90 hours

Qualification
Participants will gain first hand experiences into neuroscientific and electrophysiologically verifiable paradigms to natural signal processing in the rat brain *in vivo*. Participants will get in depth insight into the current knowledge of the somatosensory system, the visual system and the motor system. In addition, the rat’s learning and orientation system will be introduced in depth as well. Signal processing methods will be presented and for later use in exercises substantiated. Participants will learn a respectful and honorable handling of living beings, even if they are „only“ lab rats. Students will gain first hand experience with multisite electrophysiological recordings from anesthetized and freely moving animals. Signals acquired during these day long experiments will be analyzed according to state of the art and results will be presented as reports and talks.
Examination achievement
Students have to submit 4 reports. The module grade is calculated taking the average of the grades obtained for each report. If a student misses one session due to illness, an amended date for the missed lab session will be offered.
Course achievement
none

Recommendation
The experiments fall under the Animal Welfare Act - so all participants must be known by name before the first day of the experiment.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Neurophysiologie - Praktikum / Neurophysiology - Laboratory	11LE50MO-5316 PO 2021
Veranstaltung	
Neurophysiologie - Praktikum / Neurophysiology - Laboratory	
Event type	Number
Praktikum	11LE50P-5316

ECTS-Points	3.0
Workload	90 hours
Hours of week	4.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Students will in three neurophysiological paradigms (two acute, one freely behaving) under experienced supervision participate.
Students will get in depth and first hand insight into the current knowledge of the somatosensory system, the visual system and the motor system. In addition, the rat's learning and orientation system will be introduced as well.
Signal processing methods will be presented and for later use in exercises substantiated.
They will gain hands on experience with in vivo animal electrophysiology with micro devices and collect data for subsequent home based analysis.
Their analysis results will be presented as final teaching experience.

Examination achievement

see module details

Course achievement

None

Literature

- Windhorst, U. and H. Johansson (1999). Modern Techniques in Neuroscience Research. Berlin, Springer.
- Kandel, E. R., J. H. Schwartz and T. M. Jessel (1991). Principles of neural science. London, Prentice-Hall.
- D Nicolelis, M. A. L., Ed. (1999). Methods for Neural Ensemble Recordings. CRC Methods in Neuroscience. Boca Raton, FL, CRC Press.
- diverse journal papers like:
  - Wilson, M. A. and B. L. McNaughton (1994). "Reactivation of Hippocampal ensemble memories during sleep." Science 265: 676-682.
  - Wilson, M. A. and B. L. McNaughton (1993). "Dynamics of the hippocampal ensemble code for space." Science 261: 1055-1058.

Compulsory requirement

None

Recommended requirement

Prerequisite to become eligible for this course is the participation in the exercises in "Implant manufacturing technologies“ or participation in the seminar „Neuroprosthetics“ in the last winter semester.

Recommendation
The experiments fall under the Animal Welfare Act - so all participants must be known by name before the first day of the experiment.

↑

Name of module	**Number of module**
Neuroprothetik / Neuroprosthetics	11LE50MO-5318 PO 2021
Responsible	
Prof. Dr. Ulrich Hofmann	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
High school level knowledge in mathematics and natural sciences

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Neuroprothetik / Neuroprosthetics - Seminar	Seminar		3.0	3.0	90 hours

Qualification
In times of an explosion of so called bioelectronic medicine remedies, aka electroceuticals, engineering students will gain an introductory knowledge of neuroscientific basics, a profound knowledge of technical interfaces to the brain and a wide view on diseases presumbaly treated by these devices. In particular, they will investigate the pathes from bench to bedside bringing medical devices into clinical use. In the end, they will be able to critically assess business models of startups in the field of bioelectronic medicine.
Examination achievement
Written documentation in the form of a short scientific paper (5-10 pages) and oral presentation. The module grade is based on the written documentation (50%) and the oral presentation (50%).
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Neuroprothetik / Neuroprosthetics	11LE50MO-5318 PO 2021
Veranstaltung	
Neuroprothetik / Neuroprosthetics - Seminar	
Event type	Number
Seminar	04LE50V-5318

ECTS-Points	3.0
Workload	90 hours
Attendance	39 hours
Independent study	51 hours
Hours of week	3.0
Recommended semester	5
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Introductory lessons contain:
- Basic concepts of neuroscience
- Interfacing the nervous system
- Modelling approaches for CNS applications
- Neuroethical aspects

Student covered topics will contain:
- Cochlea Implant - Deafness
- Retina Implant - Blindness
- Deep Brain Stimulation - Parkinson‘s Disease
- Spinal Cord Stimulation - Chronic Pain Syndrome
- Vagal Nerve Stimulation - Epilepsy
- Functional Electrical Stimulation - Drop Foot Syndrome
- Human Machine Interfacing - BCI and BMI
- Foreign Body Reaction

Examination achievement

see module details

Course achievement

None

Literature

- Farina, D., Jensen, W., Akay, M., Eds. (2013). INTRODUCTION TO NEURAL ENGINEERING FOR MOTOR REHABILITATION, IEEE
- Dagnelie, G., Ed. (2011). Visual Prosthetics: Physiology, Bioengineering, Rehabilitation: Physiology, Bioengineering and Rehabilitation, Springer
- DiLorenzo, D. J. and J. D. Bronzino, Eds. (2008). Neuroengineering Boca Raton, CRC Press
- Akay, M. (2007). Handbook of Neural Engineering, IEEE Press, Wiley
- Dornhege, G., et al., Eds. (2007). Toward Brain-Computer Interfacing. Neural Information Processing Series. Cambridge, MA, MIT Press

- Horch, K. W. and G. S. Dhillon (2004). Neuroprosthetics - Theory and Practice. Singapore-London, World Scientific Publishing

Compulsory requirement
None
Recommended requirement
High level knowledge in mathematics and natural sciences

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Name of module	**Number of module**
Neurowissenschaften für Ingenieure / Neuroscience for Engineers	11LE50MO-5319 PO 2021
Responsible	
Prof. Dr. Ulrich Egert	
Organizer	
Institut für Mikrosystemtechnik Biomikrotechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Neurowissenschaften für Ingenieure / Neuroscience for Engineers - Vorlesung	Vorlesung		3.0	2.0	90 hours
Neurowissenschaften für Ingenieure / Neuroscience for Engineers - Übung	Übung			1.0	

Qualification
After completing this module, students will understand the fundamental neuroscientific concepts, methods, processes and structures that define or influence the function of technical components in biomedical applications.
Examination achievement
Written exam (90 min.)
Course achievement
none

Recommendation
The lecture is interdisciplinary and is offered for students of MSc Microsystems Engineering, Embedded Systems Engineering and Computer Science. If necessary the lecture will be taught in English. All slides and texts used are in English.
Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), Wahlpflichtbereich, Bereich Mikrosystemtechik Compulsory elective module for students of the study proram ■ Master of Science in Microsystems Engineering (PO 2021), concentration area Biomedical Engineering ■ Master of Science in Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ Master of Science in Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Neurowissenschaften für Ingenieure / Neuroscience for Engineers	11LE50MO-5319 PO 2021
Veranstaltung	
Neurowissenschaften für Ingenieure / Neuroscience for Engineers - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5319
Organizer	
Institut für Mikrosystemtechnik Biomikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	39 hours
Independent study	51 hours
Hours of week	2.0
Recommended semester	5
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The lecture series conveys the foundations of various neuroscientific processes, structures and measuring techniques.

We emphasize processes that
- influence the generation and properties of signals measurable with neuronal systems,
- influence the usability of MST components, such as sensors and implants,
- are relevant for typical fields of application of MST components, e.g. implantable sensors, prostheses, neurotechnology, etc..

In the course of the lectures we will present and overview of central neuroscientific concepts, tools and applications

Main topics are:
- Structure of the nervous systems
- Biophysics of electrical potentials
- Neuronal networks and their signals
- Sensory systems
- Foundations of learning and memory
- Interaction with neuronal networks

Examination achievement

see module details

Course achievement

none

Literature
Literature will be presented during the lecture
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Neurowissenschaften für Ingenieure / Neuroscience for Engineers	11LE50MO-5319 PO 2021
Veranstaltung	
Neurowissenschaften für Ingenieure / Neuroscience for Engineers - Übung	
Event type	Number
Übung	11LE50Ü-5319
Organizer	
Institut für Mikrosystemtechnik Biomikrotechnik	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see lecture
Course achievement
None
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals	11LE50MO-5312 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals - Vorlesung	Vorlesung		3.0	2.0	90 hours

Qualification
The objective of the module is to show, how signal processing and analysis methods can add additional information to the classical ways of interpreting brain signals measured by electroencephalography (EEG) or magnetoencephalography (MEG). This goes beyond the basic signal processing methods to separate the signal from background noise. General techniques for pattern recognition will be presented and how they are tailored for the daily use in clinical practice or neuroscience research. As a result students will have knowledge of general tools in pattern recognition in recordings of brain signals and how to adapt them to the requirements of the specifics needs in clinical use or for research projects. The second part of the module will add modelling to the signal analysis to perform the localization of generators of brain activity. Different approaches of modelling of the head and the generators of the brain activity will be introduced. The objective is to provide the students with knowledge about different modelling levels and strategies about the selection of generator models, which are appropriate for a given source localization task.

Examination achievement
Oral exam (30 minutes)
Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals	11LE50MO-5312 PO 2021
Veranstaltung	
Signalverarbeitung und Analyse von Gehirnsignalen / Signal processing and analysis in brain signals - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5312
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The course starts with an introduction to the basic principles of the measurement of neurophysiological signals mainly EEG and MEG. Despite a basic technical introduction of the measurement systems an overview about physiological and pathological patterns and rhythms in brain signal is given. Pattern recognition in the diagnostics of patients suffering from epilepsy is one core topic of the module. Long term recordings of EEG in epilepsy diagnostic create a high demand for automatic EEG analysis procedures. Three different types of events are at the moment in the focus for automatic detection strategies. a) Epileptic seizures, which are the core syndrome of the disease. Automatic detection may facilitate the review of long term recordings tremendously. b) Short high amplitude peaks in EEG and MEG called spikes contribute to the diagnoses of epilepsy and give information related to the localization of the seizure onset region in focal epilepsy. c) Oscillatory activity in the frequency range between 80 Hz and 600 Hz gives according to recent result probably more specific information about the seizure origin area than spikes. Signal processing and pattern recognition strategies are presented and how they can be applied to the patterns of interest in epilepsy diagnostic. In detail following strategies will be presented: a) Heuristics b) Template matching c) Wavelet transformation d) Hilbert transformation e) Background and target modelling f) Artificial neural networks A second focus of the module is related to the localization of generators of neuronal activity based on EEG and MEG measurements. The introduction starts with the presentation of the Maxwell equations and the common simplifications as they are applied in EEG and MEG source localization. Localization includes two basic components, the for-

ward simulation and an inverse parameter estimation procedure. Concepts of the following forward models representing the physical properties of the head are presented: a) Spherical model b) Boundary element model c) Finite element model Main types of focal and distributed inverse models will form the contents of the inverse part of the source localization procedure. Exemplary application examples will show the complete processing chain from measurements and image acquisition to localization results.
Examination achievement
see module details
Course achievement
None
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Siliziumbasierte Neurosonden / Silicon-based Neural Technology	11LE50MO-5116 PO 2021
Responsible	
Prof. Dr. Oliver Paul	
Organizer	
Institut für Mikrosystemtechnik Materialien der Mikrosystemtechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
Advanced Silicon Technologies for MEMS and IC

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Siliziumbasierte Neurosonden / Silicon-based Neural Technology	Vorlesung		3.0	2.0	90 hours

Qualification
Students will gain a detailed overview of silicon-based probes used in basic neuroscience research and their combination with alternative materials to provide the desired functionalities. Students will learn the basic requirements regarding system design and function, as well as the system-specific manufacturing technologies.
Examination achievement
Oral examination if there are 20 or fewer than 20 registered participants; written examination if there are more than 20 registered participants (minimum 60 and maximum 240 minutes). Details will be announced by the examiner in due time.
Course achievement
Regular attendance (2/3 of the sessions)

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Siliziumbasierte Neurosonden / Silicon-based Neural Technology	11LE50MO-5116 PO 2021
Veranstaltung	
Siliziumbasierte Neurosonden / Silicon-based Neural Technology	
Event type	Number
Vorlesung	11LE50V-5116
Organizer	
Institut für Mikrosystemtechnik Materialien der Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	5
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Introduction - Basic requirements in neuroscience
- Electrical probes
- Fluidic probes
- Optical probes
- Chemotrodes
- IC Technologies for Signal Amplification and Processing
- Packaging and interconnection technologies

Examination achievement

see module details

Course achievement

see module details

Literature

current conference and journal articles

Compulsory requirement

none

Recommended requirement

Advanced Silicon Technologies for MEMS and IC

↑

Name of module	**Number of module**
Technologien der Implantatfertigung / Implant Manufacturing Technologies	11LE50MO-5313 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Vorlesung	Vorlesung		3.0	2.0	90 hours
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Übung	Übung			1.0	

Qualification
The aim of the module is to teach the physical and technological fundamentals for manufacturing electrically active implants, to become familiar with basic structures and elements as well as methods and processes for their manufacture. The theoretical engineering basis for understanding the function and failure modes of this type of implants is provided. The module teaches students of microsystems engineering the various, basic processes on the basis of which complex implants can be realized. The exercise supplements the theoretical knowledge with practical aspects and guides the independent application of the knowledge gained.
Examination achievement
Written examination (90 minutes)

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Technologien der Implantatfertigung / Implant Manufacturing Technologies	11LE50MO-5313 PO 2021
Veranstaltung	
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5313
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	45 hours
Independent study	45 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

In the lecture Implant Manufacturing Technologies, knowledge and methods for the development of electrically active implants such as pacemakers or hearing prostheses (cochlear implants) are taught. Materials, components, systems and legal frameworks are presented. Clinically established (neuro-) implants as well as novel developments, which are still in the research phase, will be presented and critically discussed. The following topics will be covered during the lecture:

- Overview of active implants & neuroprostheses in clinical and research settings.
- Definitions and classification of electrically active implants
- Biocompatibility testing and biostability (corrosion and degradation)
- Electrodes
- Design of electrically active implants (components, interfaces)
- Silicone as material for encapsulation
- Materials for hermetically sealed housings
- Connections and joining techniques
- Requirements for implant development and production (risk management, FMEA, production rooms, documentation)
- Thin-film technology in implant development
- Manufacturing of microimplants using the example of a BION

Finally, the learning content will be repeated together with the students in order to facilitate the preparation for the examination.

Examination achievement

see module details

Course achievement

None

Compulsory requirement
None
Recommended requirement
None

↑

Name of module	Number of module
Technologien der Implantatfertigung / Implant Manufacturing Technologies	11LE50MO-5313 PO 2021
Veranstaltung	
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Übung	
Event type	Number
Übung	11LE50Ü-5313
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
none
Compulsory requirement

↑

Name of module	**Number of module**
Technologien der Implantatfertigung - Praktikum / Implant Manufacturing Technologies - Laboratory	11LE50MO-5314 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
Successful completion of the module "Technologien der Implantfertigung / Implant manufacturing technologies".
Recommended requirement
Basic knowledge in mathematics and sciences.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Technologien der Implantatfertigung - Praktikum / Implant Manufacturing Laboratory	Praktikum		3.0	4.0	90 hours

Qualification
The aim of the module is to train the skills for manufacturing electrically active implants, to become familiar with basic structures and elements as well as methods and processes for their manufacture. The theoretical engineering basis for understanding the function and failure modes of this type of implants is complemented by practical skills and experience during own manufacturing of a demonstrator of an active implant.
Examination achievement
Written test prior to each of the seven experiments. The module grade is the average of the marks obtained in the seven tests.
Course achievement
Mandatory attendance in the 12 sessions is required. In case of illness, an additional session is offered.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Technologien der Implantatfertigung - Praktikum / Implant Manufacturing Technologies - Laboratory	11LE50MO-5314 PO 2021
Veranstaltung	
Technologien der Implantatfertigung - Praktikum / Implant Manufacturing Laboratory	
Event type	Number
Praktikum	11LE50P-5314
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	52 hours
Independent study	38 hours
Hours of week	4.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

In the course of the practical exercises, the students re-build the first generation of a neuroptosthetic device, a cochlear implant. Groups with a maximum of three persons manufacture the implant in structured learning units on their own under supervision at different manufacturing setups. The learning units include:

- Laser marking and cutting
- Screen printing
- Hybrid implant assembly
- Design of pronted circuit boards
- Development and etching of printed circuit boards
- Cleansing and cleaning of substrates
- Silicone encapsulation or electronic circuits
- Packaging and sterilization
- Technical implant function test

Examination achievement

see module details

Course achievement

see module details

Compulsory requirement

Successful completion of the module "Technologien der Implantfertigung / Implant manufacturing technologies".

Recommended requirement

Basic knowledge in mathematics and sciences.

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
Responsible	
Prof. Dr. Oliver Amft	
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine | none
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Wearable and Implantable Computing (WIC)	Vorlesung		6.0	2.0	180 Stunden / Hours
Wearable and Implantable Computing (WIC)	Übung			2.0	

Qualification
Students are able to ■ Understand design concepts and apply/analyse wearable and implantable system design methods. ■ Analyse physical principles, select and optimise on-body energy harvesting and power management techniques. ■ Create context recognition and energy-efficient pattern analysis pipelines using sparse sampling and pattern processing methods. ■ Build wearable system prototypes and apply system evaluation methods, including design for biocompatibility.

Examination achievement
mündliche Prüfung (i.d.R. 30 oder 45 Minuten) | Oral exam (usually 30 or 45 minutes) If there are too many students for a reasonably organized oral exam, it will be held as a written exam instead, announced well in advance.
Course achievement
Durchführung von Versuchen und Ergebnisprotokoll | Execution of experiments and written report of results
Usability
Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Spezialvorlesung **|** Specialization Courses ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Elective Courses in Computer Science **OR** in Microsystems Engineering Concentrations Area Circuits and Systems/Biomedical Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Circuits and Systems/Biomedical Engineering ■ M.Sc.Mikrosystemtechnik (PO 2021), Vertiefung Schaltungen und Systeme/Biomedizinische Technik Part of the specialization Artificial Intelligence (AI) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering **and** Part of the specialization Cyber-Physical Systems (CPS) in Master of Science Informatik/Computer Science resp. MSc Embedded Systems Engineering

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Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
Veranstaltung	
Wearable and Implantable Computing (WIC)	
Event type	Number
Vorlesung	11E13V-1402_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	6.0
Workload	180 Stunden / Hours
Attendance	32 Stunden / Hours
Independent study	116 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The course provides students with a comprehensive overview and in-depth skills on system design of sensor-based wearable and implantable computing systems. Course covers frequent sensors and actuators and their system integration, context recognition methods and selected algorithms, powering and energy management concepts (task scheduling, sparse sampling, and on-demand signal processing), energy harvesting methods, and system design topics (flexible electronics, electronics textile integration, multiprocess additive manufacturing), as well as principles of system validation.
Examination achievement
see module details
Course achievement
see module details
Literature
Up-to-date literature recommendations are provided during the lectures.
Compulsory requirement
None
Recommended requirement
Basic timeseries analysis methods, basic programming skills, coding in Python

↑

Name of module	**Number of module**
Wearable and Implantable Computing (WIC)	11E13MO-1402_PO 2020
Veranstaltung	
Wearable and Implantable Computing (WIC)	
Event type	Number
Übung	11E13Ü-1402_PO 2020
Organizer	
Institut für Informatik Intelligente Eingebettete Systeme	

ECTS-Points	
Attendance	32 Stunden / Hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Student groups will investigate concrete cases including context recognition, energy-efficient signal processing, and digital design of wearable systems. A wearable device prototype will be realised per student group.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement

↑

Name of module	**Number of module**
Study Project in Concentration Biomedical Engineering	11LE50MO-SP MSE BE
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Faculty	
Technische Fakultät	

ECTS-Points	9.0
Workload	270 Stunden /hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
keine | none
Recommended requirement
allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Ingenieurswissenschaften, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general fundamental mathematical knowledge, practical and theoretical foundations in Engineering Sciences, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Evaluation of visual flow field uncertainty on balance control	Projekt				

Qualification
In this module students get involved in the actual research process of the chosen work group/chair in the area of Biomedical Engineering. Depending on their personal field of interest and their expertise in various research and teaching areas offered at the Department of Microsystems Engineering, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work experimentally and constructively in projects. Students acquire the ability to familiarize themselves with new engineering problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be trained.
Examination achievement
Depending on the specific project: written research paper or creation of demonstrators including a sufficient documentation or presentation and subsequent discussion

Course achievement
Regular attendance in (team) discussions or meetings with the supervisor. Self- organizing the given tasks, doing background research, presentation of results
Recommendation
Language is usually English, but might be negotiable (changed to German). Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.)

↑

Name of module	**Number of module**
Study Project in Concentration Biomedical Engineering	11LE50MO-SP MSE BE
Veranstaltung	
Evaluation of visual flow field uncertainty on balance control	
Event type	Number
Projekt	11LE50P-5997-003
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	
Hours of week	
Recommended semester	
Frequency	in jedem Semester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
Course achievement
Compulsory requirement

↑

Name of node	Number of node
Photonics	11LE50KO-WP-MSc-986-2021 WP2 P
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

↑

Name of module	**Number of module**
Gassensorik / Gas sensors	11LE50MO-5704 PO 2021
Responsible	
Prof. Dr. Jürgen Wöllenstein	
Organizer	
Institut für Mikrosystemtechnik Dünnschicht-Gassensorik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
Keine
Recommended requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Gassensorik / Gas sensors	Vorlesung		3.0	2.0	90 Stunden

Qualification
Das Ziel dieses Moduls ist die Vermittlung der physikalischen, chemischen, elektrischen Funktionsweise von Gassensoren. Dabei werden aufbauend auf den vermittelten Grundlagen typische Sensoranordnungen, Herstellungs-verfahren mit Fokus auf die Mikrosystemtechnik sowie Anwendungen der Sensoren in der Praxis vorgestellt. Die Studierenden sollen den Zusammen-hang zwischen den Messprinzip, Design, Fertigungsprozessen und dem Einsatz der Sensoren erlernen. The aim of this module is to teach the physical, chemical and electrical functions of gas sensors. Building on the fundamentals taught, typical sensor arrangements, manufacturing processes with a focus on microsystems technology and applications of the sensors in practice are presented. The students should learn the connection between the measuring principle, design, manufacturing processes and the application of the sensors.

Examination achievement
mündliche Abschlussprüfung (30 Minuten)/oral examiation (duration 30 mins.)
Course achievement
keine/none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Gassensorik / Gas sensors	11LE50MO-5704 PO 2021
Veranstaltung	
Gassensorik / Gas sensors	
Event type	Number
Vorlesung	11LE50V-5704
Organizer	
Institut für Mikrosystemtechnik Dünnschicht-Gassensorik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30 Stunden
Independent study	60 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

In der Vorlesung werden Gassensoren, die auf unterschiedlichsten, chemischen und physikalischen Prinzipien basieren, vorgestellt und deren Funktionsweise, Herstellung und Anwendung vermittelt. Gassensoren decken Massenmärkte mit sehr großen Stückzahlen ebenso ab, wie applikationsspezifische Sonderlösungen. Folgende wichtige Grundlagen für die Gassensorik werden diskutiert:

- Wechselwirkung Gas-Halbleiter, Adsorption, Elektrische Auswirkungen von adsorbierten Gasen
- Wärmeleitung u. –kapazität, Paramagnetismus von Gasen
- Schwingungs- und Rotationsspektren im IR, Druck- und Dopplerverbreiterung, Linienformen
- Interferometer, Schwarzkörperstrahlung, Elektrochemie

Folgende Bauelemente und Messsysteme werden vorgestellt:

- Metalloxidgassensoren, Lambdasonde, Gassensitive Feldeffekttransistoren
- Wärmeleitfähigkeitssensoren, Pelistoren
- Paramagnetischer Sauerstoffsensor
- Optische Systeme (Laserspektrometer, Filterphotometer, Photoakustik, Wellenleiter), Fourier Transformations Infrarot Spektrometer
- Elektrochemische Sensoren, Elektronische Nasen

Examination achievement

siehe Modulebene

Course achievement

keine

Literature

Begleitend zur Vorlesung wird ein Folien-Skriptum zur Verfügung gestellt.

Compulsory requirement

Keine

Recommended requirement
Keine

↑

Name of module	**Number of module**
Lasers	11LE50MO-5266 PO 2021
Responsible	
PD Dr. Ingo Breunig	
Organizer	
Institut für Mikrosystemtechnik Optische Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
It is recommended to have attended the "Micro-optics" lecture before atteding this course.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
			3.0		

Qualification
Lasers are versatile tools with a high relevance for microsystems engineering. In this course, the students gain knowledge about different types of lasers and their respective applications. They achieve a deeper understanding on the fundamentals of laser operation. Consequently, the participants will be able to - Select an appropriate laser for a given task - Better design microsystems including lasers - Easier understand already existing systems
Usability
Students of the M.Sc. programmes Microsystems Engg. and Mikrosystemtechnik (PO 2021) can select this module in the concentration area Photonics (Photonik).

↑

Name of module	Number of module
Lasers	11LE50MO-5266 PO 2021
Lasers	
Event type	

ECTS-Points	3.0
Hours of week	
Recommended semester	2
Frequency	
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	Number of module
Physics of Microscopy and Optical Image Formation	11LE50MO-5902 PO 2021
Responsible	
Prof. Dr. Alexander Rohrbach	
Organizer	
Institut für Mikrosystemtechnik Bio- und Nano-Photonik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Physics of Microscopy and Optical Image Formation	Vorlesung		6.0	3.0	180 hours
Physics of Microscopy and Optical Image Formation	Übung			2.0	

Qualification
The students shall understand how light can be guided through optical systems, how optical information can be described effectively by three-dimensional transfer functions in Fourier space, how the phase information of a wave can be transferred into amplitude information to produce image contrast. Furthermore, the students will learn to distinguish coherent and incoherent imaging techniques and learn about state-of-the-art techniques with self-reconstructing beams, two photon excitation, fluorophore depletion by stimulated emission (STED) or multi-wavelength mixing as in coherent anti-Stokes Raman scattering (CARS). This module is a application-oriented mixture of fundamental physics, conceivable mathematical theories and numerous examples and images and tries to convey the latest state of this particular scientific discipline, which will massively influence the areas of nanotechnology, biology and medicine in the next years.
Examination achievement
Up to 6 students: oral exam (40 minutes) 7 or more students: written exam (120 minutes)

Course achievement
In order to meet the requirements of the "Studienleistung", the students have to treat a minimum of 60% of the tutorial exercises, and additionally present minimum two exercises in the tutorials.
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Physics of Microscopy and Optical Image Formation	11LE50MO-5902 PO 2021
Veranstaltung	
Physics of Microscopy and Optical Image Formation	
Event type	Number
Vorlesung	11LE50V-5902
Organizer	
Institut für Mikrosystemtechnik Bio- und Nano-Photonik	

ECTS-Points	6.0
Workload	180 hours
Attendance	75 hours
Independent study	105 hours
Hours of week	3.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

1. Microscopy: History, Presence and Future
1.1 History
1.2 Present and Future Tasks
1.3 Literature

2. Wave- and Fourier-Optics
2.1 What is Light?
2.2 The change of Light in Matter
2.3 Helmholtz equation and plane waves
2.4 Wave functions in space and frequency domain
2.5 Superposition of waves: Interference and Coherence
2.6 Fourier-Optics
2.7 Wave propagation and diffraction

3. Three-dimensional optical imaging and information transfer
3.1 Imaging through lenses
3.2 Optical image formation – a spatial low-pass filtering
3.3 Optical resolution and optical transfer function
3.4 Coherent and incoherent imaging
3.5 Vectorial light focusing
3.6 Aberrations of the Point-Spread Function

4. Contrast enhancement by Fourier-filtering
4.1 Image formation with phase objects
4.2 Phase contrast according to Zernike
4.3 Dark field microscopy and amplitude spatial filters
4.4 Generating contrast by polarization
4.5 Holographic microscopy

5. Fluorescence – Basics and Techniques
5.1 Definitions and principles of light scattering
5.2 Fluorescence excitation und emission
5.3 Decay rates and fluorescence lifetime
5.4 Fluorescence Polarisation and Anisotropy

6. Point scanning and confocal microscopy
6.1 Image formation with point- and area-detectors
6.2 Confocal microscopy
6.3 4pi Microscopy

7. Microscopy in thick media
7.1 Photon diffusion in strongly scattering media
7.2 Light Sheet Microscopy
7.3 Microscopy with holographic scan beams
7.4 Lattice light-sheet microscopy

8. Nearfield and Evanescent Field Microscopy
8.1 The spectrum of near fields and far fields
8.2 Nearfield Scanning Optical Microscopy (NSOM)
8.3 Evanescent illumination and TIR- Microscopy

9. Super-resolution by structured illumination
9.1 Modulated illumination to increase resolution
9.2 Structured illumination for axial sectioning

10. Multi-Photon-Microscopy
10.1 Basics of nonlinear optics
10.2 Two-photon fluorescence microscopy
10.3 Second Harmonic Generation-Microscopy
10.4 CARS microscopy

11. Super-resolution imaging by switching single molecules
11.1 Position tracking
11.2 STED-Microscopy
11.3 PALM and STORM
11.4 Super-resolution optical fluctuation imaging (SOFI)

12. Appendix
12.1 Signal and Noise
12.2 Survey about super resolution microscopy

Examination achievement
see module details
Course achievement
see module details
Literature
An additional scriptum with defined blank areas (white boxes), accompanying the lecture contents, will be provided.
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Physics of Microscopy and Optical Image Formation	11LE50MO-5902 PO 2021
Veranstaltung	
Physics of Microscopy and Optical Image Formation	
Event type	Number
Übung	11LE50Ü-5902
Organizer	
Institut für Mikrosystemtechnik Bio- und Nano-Photonik	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The tutorials help the student to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this the students should prepare weekly exercises and present them during the tutorial. Only difficult exercises may be presented by the tutors.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Nano-Photonics - Optical manipulation and particle dynamics	11LE50MO-5281 PO 2021
Responsible	
Prof. Dr. Alexander Rohrbach	
Organizer	
Institut für Mikrosystemtechnik Bio- und Nano-Photonik	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 h
Recommended semester	4
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
Basic courses in mathematics and physics, foundations of optics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Nano-Photonics - Optical manipulation and particle dynamics	Vorlesung		6.0	3.0	180 h
Nano-Photonics - Optical manipulation and particle dynamics	Übung			2.0	

Qualification
You think basic physics research and applied research leading to a social benefit cannot be well combined? When particles or macro-molecules undergo thermal collisions with smaller molecules in (complex) fluids or in air, thermal (Brownian) motion with stochastic changes in positions and velocities take place - beyond our imagination. Such particles can be viruses or particulates from combustion engines in the air that get into contact with e.g. lung cells. How can a limited number of photons be generated in such a way that they scatter efficiently at the small, fast particles and carry the maximum information with them. How can the particle information encoded by the scattered photons be amplified by intelligent detection mechanisms? How can rare but important interaction events be manipulated by photon momentum transfer and optical forces?
Examination achievement
Written exam (120 minutes)

Course achievement
There are exercises at regular intervals that have to be worked on and handed in.These are corrected and assessed with points. The course work is considered succesfully passed when the student has submitted 60% of the exercises and demonstrated the solution of two assignments during the exercise sessions.
Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ Bachelor of Science in Mikrosystemtechnik (PO 2018) im Wahlpflichtbereich, Bereich Mikrosystemtechnik Compulsory elective module for students of the study program ■ Master of Science in Microsystems Engineering (PO 2021), concentration area Photonics ■ Master of Science in Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ Master of Science in Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	Number of module
Nano-Photonics - Optical manipulation and particle dynamics	11LE50MO-5281 PO 2021
Veranstaltung	
Nano-Photonics - Optical manipulation and particle dynamics	
Event type	Number
Vorlesung	11LE50V-5281
Organizer	
Institut für Mikrosystemtechnik Bio- und Nano-Photonik	

ECTS-Points	6.0
Workload	180 h
Attendance	65 h
Independent study	115 h
Hours of week	3.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Motivation:

You think basic physics research and applied research leading to a social benefit cannot be well combined? When particles or macro-molecules undergo thermal collisions with smaller molecules in (complex) fluids or in air, thermal (Brownian) motion with stochastic changes in positions and velocities take place - beyond our imagination. Such particles can be viruses or particulates from combustion engines in the air that get into contact with e.g. lung cells. How can a limited number of photons be generated in such a way that they scatter efficiently at the small, fast particles and carry the maximum information with them. How can the particle information encoded by the scattered photons be amplified by intelligent detection mechanisms? How can rare but important interaction events be manipulated by photon momentum transfer and optical forces?

In this lecture you will learn
- the transfer from the Maxwell equations and the electromagnetic force density to optical forces and optical tweezers, which allow to control molecular processes relevant to cellular biology and medicine
- the basics of light scattering, how photons transfer momentum to microscopic objects and how scattered photons transfer information about the state of the objects. In contrast to incoherent photons, coherent light encodes significantly more information about small objects, which, driven by thermal forces, continuously change their position and orientation relative to their environment. All this can be directly measured through µs-nm particle tracking.
- how smallest probes can interact on a molecular scale with their environment, which can be analyzed by correlations of changes in the probe’s states. In this way, the interactions of probes with living cells give new insights into cellular diseases, such as bacterial and viral infections, but also exposure of particulate matter to lung cells.
The summer term lecture “Wave Optics” is quite helpful to hear, but not mandatory.

Contents
- Introduction
- Light – Carrier of Information and Actor

- Microscopy und Light Focussing
- Light Scattering
- Manipulation by Optical Forces
- Particle Tracking beyond the Uncertainty Regime
- Thermal Motion and Calibration
- Photonic Force Microscopy
- Applications in Biophysics and Medicine
- Time-Multiplexing and holographic optical traps
- Applications in Micro- and Nano-Technology
- Appendix

Examination achievement
see module details
Course achievement
see module details
Literature
Accompanying to the lecture printed lecture notes with defined gaps (white boxes) are distributed.
Compulsory requirement
None
Recommended requirement
Basic courses in mathematics and physics, foundations of optics

↑

Name of module	**Number of module**
Nano-Photonics - Optical manipulation and particle dynamics	11LE50MO-5281 PO 2021
Veranstaltung	
Nano-Photonics - Optical manipulation and particle dynamics	
Event type	Number
Übung	11LE50Ü-5281
Organizer	
Institut für Mikrosystemtechnik Bio- und Nano-Photonik	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The tutorials help the students to get a more in depth and thorough understanding of the lecture. Here, a special focus is put on the transfer of knowledge obtained in the lecture. To achieve this the students should prepare weekly exercise and present them during the tutorial. Only difficult exercises are presented by the tutors.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
Basic courses in mathematics and physics, foundations of optics

↑

Name of module	**Number of module**
Optik-Praktikum Grundlagen / Basic Optics Laboratory	11LE50MO-5213 PO 2021
Responsible	
Prof. Dr. Hans Zappe	
Organizer	
Institut für Mikrosystemtechnik Mikrooptik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
BSc. level in physics and mathematics; MSc. course Micro-optics.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Optik-Praktikum Grundlagen / Basic Optics Laboratory	Praktikum		3.0	2.0	90 hours

Qualification

The Basic Optics Laboratory provides an opportunity for hands-on experimentation on the topics introduced in the Micro-optics course. As a result, the students will develop expertise in the design, assembly and characterization of optical systems and become experienced in making optical measurements.
At the completion of the course, the successful student should possess:

- the ability to analyze measurement data and estimate errors;
- the ability to apply error propagation methods;
- the ability to assemble and align optical systems;
- a basic understanding of optical design methods;
- the ability to apply optical measurement techniques;
- the ability to apply analytical and graphical techniques for analyzing optical images.

Examination achievement

A laboratory report is required for each of the 8 experiments. The overall grade will be the average of the grades of the individual laboratory reports. All experiments must be performed and a lab report written. In case of illness an amended date for the missed experiment will be offered.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	Number of module
Optik-Praktikum Grundlagen / Basic Optics Laboratory	11LE50MO-5213 PO 2021
Veranstaltung	
Optik-Praktikum Grundlagen / Basic Optics Laboratory	
Event type	Number
Praktikum	11LE50P-5213-2
Organizer	
Institut für Mikrosystemtechnik Mikrooptik	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	2.0
Recommended semester	4
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

One laboratory experiment has been conceived for each of the important topics addressed in the Micro-optics course; a different experiment is performed each week of the laboratory course. The topics addressed include geometric, reflective, diffractive and fiber optics as well as Fourier optics, interference, diffraction and polarization. To allow adequate representation and analysis of the measured experimental data, the course begins with a compact mini-lecture on data analysis.
Table of contents:
1. Statistics and data analysis
2. Error propagation
3. Focal length of lenses
4. Focal length of lens systems
5. Construction of a microscope
6. Diffraction from gratings
7. Newton’s rings
8. Fiber optics
9. Construction of an interferometer
10. Polarization

Examination achievement

see module details

Course achievement

None

Literature

In German:
- E. Hecht: Optik
- Walcher: Praktikum der Physik
- Westphal: Physikalisches Praktikum
- Geschke: Physikalisches Praktikum

In English: ■ H. Zappe: Fundamentals of Micro-optics ■ E. Hecht: Optics ■ B. Saleh & M. Teich: Fundamentals of Photonics ■ S. Sinziger & J. Jahns: Microoptics ■ W. Smith: Modern Optical Engineering ■ P. Hariharan: Basics of interferometry ■ R.R. Shannon: The art and science of optical design ■ D. Malacara: Optical shop testing ■ W.J. Smith: Practical optical system layout
Compulsory requirement
None
Recommended requirement
BSc. level in physics and mathematics; MSc. course Micro-optics.
Recommendation
Participants in this laboratory course will work in groups on the ten experimental modules. Individual guidance will be in English and German according to preference. Instruction manuals in English and German will be made available.

↑

Name of module	Number of module
Optik-Praktikum Fortgeschritten / Advanced Optics Laboratory	11LE50MO-5280 PO 2021
Responsible	
Prof. Dr. Hans Zappe	
Organizer	
Institut für Mikrosystemtechnik Mikrooptik	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	30 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
Successful participation in the 'Basic Optics Laboratory' is a prerequisite.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Optik-Praktikum Fortgeschritten / Advanced Optics Laboratory	Praktikum		3.0	2.0	90 hours

Qualification
The students will develop advanced expertise in the design, assembly and characterization of optical systems and become experienced in understanding physics in optical systems. At the completion of the course, the students will possess: ■ the ability to design optical systems ■ the ability to assemble and align complex optical systems ■ the ability to analyze the properties of optical systems ■ an insight into modern optical experiments ■ advanced knowledge in analyzing experimental results ■ an understanding of physics in optical setups
Examination achievement
A laboratory report is required for each of the 6 experiments. The overall grade will be the average of the grades of the individual laboratory reports. All experiments must be performed and a lab report written. In case of illness an amended date for the missed experiment will be offered.

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Optik-Praktikum Fortgeschritten / Advanced Optics Laboratory	11LE50MO-5280 PO 2021
Veranstaltung	
Optik-Praktikum Fortgeschritten / Advanced Optics Laboratory	
Event type	Number
Praktikum	11LE50P-5217-2
Organizer	
Institut für Mikrosystemtechnik Mikrooptik	

ECTS-Points	3.0
Workload	90 hours
Attendance	30 hours
Independent study	60 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

This advanced Optics Lab Course provides an opportunity for hands-on experimentation on topics introduced in the different optics courses at IMTEK. The course is based on the knowledge acquired in the 'Basic Optics Laboratory' which is a prerequisite.

Table of contents:
- Anamorphic imaging
- Dynamically addressable gratings
- Whispering gallery resonators
- Michelson interferometer and coherence
- Three dimensional light distribution in a 6f system
- Diode pumped solid state laser

Examination achievement

see module details

Course achievement

None

Literature

In German:
- Naumann/Schröder: Bauelemente der Optik
- E. Hecht: Optik
- Walcher: Praktikum der Physik
- Westphal: Physikalisches Praktikum
- Geschke: Physikalisches Praktikum

In English:
- H. Zappe: Fundamentals of Micro-optics

- Goodman: Introduction to Fourier Optics
- E. Hecht: Optics
- B. Saleh & M. Teich: Fundamentals of Photonics
- W. Smith: Modern Optical Engineering
- P. Hariharan: Basics of interferometry
- R.R. Shannon: The art and science of optical design
- W.J. Smith: Practical optical system layout

Compulsory requirement
Successful participation in the 'Basic Optics Laboratory' is a prerequisite
Recommended requirement
None
Recommendation
Participants in this laboratory course will work in groups on the ten experimental modules. Individual guidance will be in English and German according to preference. Instruction manuals in English and German will be made available.

↑

Name of module	Number of module
Optische Materialien / Optical Materials	11LE50MO-5113-2 PO 2021
Responsible	
Prof. Dr. Karsten Buse	
Organizer	
Institut für Mikrosystemtechnik Optische Systeme	
Faculty	
Technische Fakultät Albert-Ludwigs-Universität Freiburg	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
It is strongly recommended to attend the Micro-optics lecture before attending this course.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Optische Materialien / Optical Materials - Vorlesung	Vorlesung			2.0	180 hours
Optische Materialien / Optical Materials - Übung	Übung			2.0	

Qualification
Optical devices rely on optical materials that control the propagation (lenses, fibers), the polarization (half-wave plates, Faraday rotators), or the frequency (nonlinear-optical materials) of light. In this course, we will classify optical materials and cover the fundamentals of light-matter interaction as well as effects that are widely used in many applications. Our goal is to enable the participants to understand important optical devices from the material point-of-view and to qualify the attendees to select the right material for a particular application.
Examination achievement
Written exam (150 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	**Number of module**
Optische Materialien / Optical Materials	11LE50MO-5113-2 PO 2021
Veranstaltung	
Optische Materialien / Optical Materials - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5113
Organizer	
Institut für Mikrosystemtechnik Optische Systeme	

ECTS-Points	
Workload	180 hours
Attendance	60 hours
Independent study	120 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

1. Classification of optical materials
2. Fabrication
3. Interaction of light and matter
4. Pulse propagation in dispersive materials
5. Birefringence
6. Faraday effect
7. Nonlinear-optical effects
8. Pockels effect
9. Kerr effect
10. Photorefractivity
11. Frequency conversion
12. Optical parametric oscillators
13. Optical whispering galleries

Examination achievement

see module details

Course achievement

None

Literature

- B. E. A. Saleh, M. C. Teich, „Grundlagen der Photonik“
- A. Yariv, "Photonics: Optical Electronics in Modern Communications"

Compulsory requirement

None

Recommended requirement
It is strongly recommended to attend the Micro-optics lecture before attending this course.

↑

Name of module	**Number of module**
Optische Materialien / Optical Materials	11LE50MO-5113-2 PO 2021
Veranstaltung	
Optische Materialien / Optical Materials - Übung	
Event type	Number
Übung	11LE50Ü-5113
Organizer	
Institut für Mikrosystemtechnik Optische Systeme	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
See module details
Course achievement
None
Compulsory requirement

↑

Name of module	**Number of module**
Optische MEMS / Optical MEMS	11LE50MO-5240 PO 2021
Responsible	
Prof. Dr. Hans Zappe	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik Mikrooptik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	4
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
It is strongly recommended to successfully complete the Micro-optics module before taking this course.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Optische MEMS / Optical MEMS - Vorlesung	Vorlesung		3.0	2.0	90 hours

Qualification
■ Theoretical understanding of fundamental optical phenomena exploited by the MOEMS technology ■ Acquisition of the essential skills necessary for the design, microfabrication, modeling, and characterization of MEMS/MOEMS components ■ A comprehensive knowledge of MOEMS based commercial systems and a basic understanding of the particular applications enabled by MOEMS
Examination achievement
Written exam (100 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	Number of module
Optische MEMS / Optical MEMS	11LE50MO-5240 PO 2021
Veranstaltung	
Optische MEMS / Optical MEMS - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5240

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Module1: MOEMS Fundamentals
• Optics Review
• MEMS Manufacturing Techniques
• Actuators and Position Sensing
• Design and Modeling
• Test and Characterization

Module 2: MOEMS Devices
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• Tunable Gratings
• Active Microlenses
• Tunable Optical Resonators

Module 3: MOEMS Systems
• Display and Imaging Systems
• MOEMS in Telecommunication Networks
• Scientific Instrumentation

Examination achievement

see module details

Course achievement

none

Literature

MEMS and MOEMS Related Books
- An Introduction to Microelectromechanical Systems Engineering by N. Maluf
- Microsystem Design by Stephen Senturia
- Micromachined Transducers Sourcebook by G. Kovacs
- Fundamentals of Microfabrication by Marc Madou
- Micro Electro Mechanical System Design by J. Allen
- Analysis and Design Principles of MEMS Devices by Minhang Bao

- The MEMS Handbook by Mohamed Gad-el-Hak
- MOEMS: Micro-Opto-Electro-Mechanical Systems by Manouchehr E. Motamedi
- Foundations of MEMS by Chang Liu
- MEMS & Microsystems by Tai-Ran Hsu

Scientific Journals

- Journal of Microelectromechanical Systems / IEEE
- Journal of Micromechanics and Microengineering / IOP
- Journal of Micro/Nanolithography, MEMS, and MOEMS / SPIE
- Microsystem Technologies / SPRINGER
- Sensors and Actuators A-Physical / ELSEVIER
- Applied Optics / OSA
- Optics Letters / OSA
- Optics Express / OSA
- Applied Physics Letters / AIP
- Journal of Biomedical Optics / SPIE

Compulsory requirement
None
Recommended requirement
It is strongly recommended to successfully complete the Micro-optics module before taking this course.

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Name of module	**Number of module**
Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques	11LE50MO-5710 PO 2021
Responsible	
Prof. Dr. Karsten Buse	
Organizer	
Institut für Mikrosystemtechnik Optische Systeme	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques - Seminar	Seminar		3.0	2.0	90 hours

Qualification
The students gain knowledge about different optical measurement techniques for shape determination of objects or for material characterization. They achieve a deeper understanding of the physical background. Consequently, the participants are able to estimate the fundamental and technological limitations of the methods presented. This enables the students to select an appropriate optical measurement technique for a given task. Furthermore, the participants get trained in preparing and presenting excellent talks.
Examination achievement
Written composition in the form of a short scientific paper (5-10 pages) and oral presentation (duration 30 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

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Name of module	**Number of module**
Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques	11LE50MO-5710 PO 2021
Veranstaltung	
Optische Messverfahren: Grundlagen und Anwendungen in der Praxis / Optical measurement techniques - Seminar	
Event type	Number
Seminar	11LE50V-5710
Organizer	
Institut für Mikrosystemtechnik Optische Systeme	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

During the first meeting the organizers will present a list of topics from which each active participant of the seminar can select one. For each topic literature will be provided. Starting with this material the active participants of the seminar will familiarize themselves with the content. This will be done by discussions as well as by further literature search. Based on the accumulated knowledge, an outline for talks will be made and finally the viewgraphs will be prepared. Then the talk will be presented in the seminar. Typical duration of the talk is 30 minutes. After the talk there will be a discussion about the content. And as a second part of the discussion technical issues of the talk will be analyzed. Finally, a short written summary of the talk will be prepared. Talks can be given in German or English.

This semester, the following topics are available:

- 3d-shape determination
- Optical microresonators for sensing
- Terahertz waves for material characterization
- Photoacoustic spectroscopy
- Laser spectroscopy
- Fluorescence spectroscopy
- and more

Examination achievement

see module details

Course achievement

None

Literature

The advisor will provide literature as a starting package.

Compulsory requirement
None
Recommended requirement
None

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Name of module	Number of module
Optical metrology for quality assurance in sustainable production	11LE50MO-4305 PO 2021
Responsible	
Dr. Daniel Carl	
Organizer	
Institut für Nachhaltige Technische Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	3
Workload	90 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
Keine
Recommended requirement
Fundamental knowledge about photonics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Optical metrology for quality assurance in sustainable production - Vorlesung	Vorlesung		3.0	2.0	90 h

Qualification

Metrology plays for the majority of manufacturers one of the most important roles in quality control, being essential to avoid production of “non-good” parts and hence to stop wasting of energy, materials, and productivity. Here optics helps to make efficient use of resources and to produce high-quality parts and goods that finally really work for a long period of use. This are immediate benefits for a more sustainable world. Since here economic and environmental aspects are in line, penetration of this technology is happening. The key is to identify the chances and to develop the tailored, reliable optical metrology to do this job.

Within this context, the lecture gives insights into the fundamental principles and methods of optical metrology for production control.

In detail, the students will learn
- Basic principles of geometrical optical measurements,
- Fundamentals of wave optics,
- Operation of optical sensors,
- Principles of digital data/image processing,
- Different optical measurement methods and their applications.

- Schematics to identify opportunities to improve the efficiency of production processes by optical metrology

Examination achievement
Final written supervised exam (90 minutes) 5 topics with 3-5 questions on each topic
Course achievement
Keine / none.
Grading
Die Modulnote errechnet sich zu 100% aus der schriftlichen Abschlussprüfung.
Examination weight
■ Master of Science im Fach Sustainable Systems Engineering, Prüfungsordnungsversion 2016: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
Literature
- LEACH, Richard (Hg.). Optical measurement of surface topography. Berlin: Springer, 2011. - Saleh, Bahaa EA, and Malvin Carl Teich. Fundamentals of photonics. John Wiley & Sons, 2019.
Usability
Wahlmodul für Studierende des Studiengangs / Elective module for students in the programme ■ Master of Science in Sustainable Systems Engineering -Reslilienz / Resilience Engineering ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

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Name of module	Number of module
Optical metrology for quality assurance in sustainable production	11LE50MO-4305 PO 2021
Veranstaltung	
Optical metrology for quality assurance in sustainable production - Vorlesung	
Event type	Number
Vorlesung	11LE68V-4305

ECTS-Points	3.0
Workload	90 h
Attendance	26 h
Independent study	64 h
Hours of week	2.0
Recommended semester	
Frequency	unregelmäßig
Pflicht/Wahlpflicht (P/WP)	

Contents

- Basic principles of geometrical optical measurements
- Fundamentals of wave optics
- Optical Sensors
- Overview of optical measurement principles and their applications
- Incoherent methods (Triangulation, Fringe projection, …)
- Coherent methods (Interferometry, Speckle, Holography, …)
- Confocal methods
- Examples for successful implementation of optical metrology in industry, with economical and sustainability win-win situations

The lecture includes an excursion to production control laboratories at Fraunhofer IPM.

Examination achievement

See module

Course achievement

See module

Literature

- LEACH, Richard (Hg.). Optical measurement of surface topography. Berlin: Springer, 2011.
- Saleh, Bahaa EA, and Malvin Carl Teich. Fundamentals of photonics. John Wiley & Sons, 2019.

Compulsory requirement

None

Recommended requirement

Fundamental knowledge about photonics

Teaching method

Lecture

↑

Name of module	**Number of module**
Optoelektronik / Optoelectronics	11LE50MO-5229 PO 2021
Responsible	
Prof. Dr. Hans Zappe	
Organizer	
Institut für Mikrosystemtechnik Mikrooptik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	4
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
Students need to have passed the final exam in Micro-optics.
Recommended requirement
BSc. level physics and mathematics; MSc course Micro-optics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Optoelektronik / Optoelectronics	Vorlesung		3.0	2.0	90 hours

Qualification

Optoelectronics is situated at the overlap between optics and electronics and forms the core of the field of photonics. Lasers and LEDs are essential optical semiconductor devices which form the basis for technologies ranging from world-wide high-speed optical data networks to advanced medical instrumentation to high-efficiency indoor lighting.

This course covers the optoelectronics field and introduces the student to the physical principles underlying lasers and quantum light emission; the III-V materials on which almost all optoelectronic components are based; the structure and functionality of laser diodes, LEDs, photodetectors and modulators; and a wide variety of applications for optoelectronic components.

At the completion of the course, the successful student should possess:

- the ability to understand and analyze the essential properties of lasers;
- the ability to understand and analyze the essential properties of photodetectors and modulators;
- an understanding of the basics of III-V materials and their fabrication;
- an awareness of the important physical phenomena on which optoelectronics relies;
- a basic understanding of the physical processes underlying quantum electronics;
- the ability to understand and apply optoelectronic components to microsystems applications;

- the ability to research, plan, and write a technical paper of a standard required for a scientific publication.

Examination achievement
To receive credit for the course, the student will be required to research, write and submit a four-page written paper, using the style of international scientific journals, on a topic related to optoelectronics.
Course achievement
The course work is passed if students have earned at least 25 points on the lecture quizzes (10 quizzes, maximum 3 points each)
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

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Name of module	Number of module
Optoelektronik / Optoelectronics	11LE50MO-5229 PO 2021
Veranstaltung	
Optoelektronik / Optoelectronics	
Event type	Number
Vorlesung	11LE50V-5229
Organizer	
Institut für Mikrosystemtechnik Mikrooptik	

ECTS-Points	3.0
Workload	90 hours
Attendance	26 hours
Independent study	64 Stunden
Hours of week	2.0
Recommended semester	4
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The course considers optoelectronics from the basic photonic and electronic processes, through the materials required, to the individual structures and functionality of the most essential optoelectronic components.

1. Quantum light
2. Materials
3. Light-emitting diodes
4. Lasers
5. Macroscopic lasers
6. Laser diodes
7. Characterization
8. Photodetectors
9. Modulators
10. Applications: communications & medicine

Examination achievement

see module details

Course achievement

see module details

Literature

- A. Yariv: Optical Electronics
- A. Siegmann: Lasers
- H. Zappe: Laser Diode Microsystems
- M. Fukuda: Optical Semiconductor Devices W.T. Silfvast: Laser Fundamentals

Compulsory requirement

None

Recommended requirement
BSc. level physics and mathematics; MSc course Micro-optics

↑

Name of module	**Number of module**
Responsible	
Faculty	

ECTS-Points	
Workload	
Recommended semester	2
Duration	
Pflicht/Wahlpflicht (P/WP)	

Compulsory requirement

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
			3.0		

Qualification

↑

Name of module	**Number of module**
Optische Mikrosensoren / Optical Micro-Sensors - Vorlesung	
Event type	

ECTS-Points	3.0
Hours of week	
Recommended semester	2
Frequency	
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	Number of module
Spektroskopische Methoden	11LE50MO-5717 PO 2021
Responsible	
Prof. Dr. Jürgen Wöllenstein	
Organizer	
Institut für Mikrosystemtechnik Dünnschicht-Gassensorik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
keine
Recommended requirement
keine

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Spektroskopische Methoden	Vorlesung		3.0	2.0	90 Stunden

Qualification
Das Ziel des Moduls ist die Vermittlung der physikalischen Grundlagen und Bauteile moderner spektroskopischer Systeme. Dabei werden aufbauend auf den vermittelten Grundlagen typische Systeme, Modultechnologien und Anwendungen vorgestellt. Die Studierenden sollen die Funktionsweise und den Aufbau spektroskopischer Geräte verstehen und deren Anwendungsgebiete und Anforderungen erlernen. The aim of the module is to teach the physical fundamentals and components of modern spectroscopic systems. Building on the fundamentals taught, typical systems, module technologies and applications are presented. Students will understand the operation and design of spectroscopic devices and learn their application areas and requirements.
Examination achievement
Oral exam (30 minutes) If the number of participants is rather high, a written exam may be held instead. The students will informed in good time.

Course achievement
keine/none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

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Name of module	**Number of module**
Spektroskopische Methoden	11LE50MO-5717 PO 2021
Veranstaltung	
Spektroskopische Methoden	
Event type	Number
Vorlesung	11LE50V-5717
Organizer	
Institut für Mikrosystemtechnik Dünnschicht-Gassensorik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26 Stunden
Independent study	64 Stunden
Hours of week	2.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Spektroskopische Anwendungen finden sich einer Vielzahl von Industrien, der Anwendungsorientierten- und Grundlagenforschung. In der Vorlesung wird ein Verständnis der physikalischen Grundlagen der verschiedenen Spektroskopietechniken und häufig verwendeten Komponenten vermittelt. Der Stand der Technik der verschiedenen Systeme wird vorgestellt.
Examination achievement
siehe Modulebene
Course achievement
keine
Literature
Begleitend zur Vorlesung werden die verwendeten Folien zur Verfügung gestellt.
Compulsory requirement
keine
Recommended requirement
keine

↑

Name of module	**Number of module**
Wave Optics	11LE50MO-5221 PO 2021
Responsible	
Prof. Dr. Alexander Rohrbach	
Organizer	
Institut für Mikrosystemtechnik Bio- und Nano-Photonik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Wave Optics	Vorlesung		6.0	3.0	180 hours
Wave Optics	Übung			2.0	

Qualification
The students understand how light interacts with small structures and how optical systems guide light. They know Maxwell's equations and the description of light as photon or wave, depending on the given problem. Furthermore, they understand the close connection between spatial and temporal coherence, interference and holography. The students also know the concepts of linear and non-linear light scattering, as well as the most important plasmonic effects. In total, the students know how to shape light in three dimensions and how optical problems that arise in research and development are solved.
Examination achievement
For 6 or less students oral exam (40 min.), for 7 or more students written exam (120 min.)
Course achievement
The course work is considered succesfully passed when the student has submitted 60% of the exercises and demonstrated the solution of two assignments during the exercise sessions.

Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ Bachelor of Science in Mikrosystemtechnik (PO 2018), im Wahlpflichtbereich, Bereich Mikrosystemtechnik Compulsory elective module for students of the study pogram ■ M.Sc. Microsystems Engineering (PO 2021), concentration area Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area Photonics

↑

Name of module	Number of module
Wave Optics	11LE50MO-5221 PO 2021
Veranstaltung	
Wave Optics	
Event type	Number
Vorlesung	11LE50V-5221
Organizer	
Institut für Mikrosystemtechnik Bio- und Nano-Photonik	

ECTS-Points	6.0
Workload	180 hours
Attendance	65 hours
Independent study	115 hours
Hours of week	3.0
Recommended semester	4
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

--- in English ---

We do not really know what light is, although the concepts to describe light as waves or as particles usually work well. It is a nontrivial task to explain the colorful intensity distributions we see every day, i.e. the interactions of light with matter. Controlling light on the macroscale and the nanoscale is the key for generating impact in research, development and industry. However, this requires a thorough understanding of wave optics and its powerful theoretical instrument, the description by Fourier transforms.
This english lecture is accompanied by many live experiments and by weekly tutorials, where exercises are discussed that students have to calculate from one week to the next.
The new lecture is a fusion of the two former lectures “Moderne Optik I & II“ and is now organized in 6 chapters.

1. Introduction
Some motivation, literature and a bit of history

2. From Electromagnetic Theory to Optics
What is light ? Which illustrative pictures do the Maxwell equations provide? If matter, dielectric and metallic, consists of coupled, damped springs (harmonic oscillators), how does matter depend on the frequency of light ? What do the wave equation and the Helmholtz equation express and how can one handle waves in position space and frequency space.

3. Fourier-Optics
How does a wave transforms position information into directional information ? Why can this be well described by Fourier transformations in 1D, 2D and 3D ? What has this to do with linear optical system theory including spatial frequency filters and the sampling theorem?

4. Wave-optical Light Propagation and Diffraction
Different methods are introduced of how to describe the propagation of ways in position space and frequency space. We do the direct transfer from propagation to diffraction of light and momentum space. We

treat evanescent waves, thin diffracted objects, the propagation of light in inhomogeneous media and the diffraction at gratings. This allows to discuss important active elements such as acousto-optic and spatial light modulators. We end with adaptive optics and phase conjugation.

5. Interference, Coherence and Holography
We learn how a composition of k-vectors define the phases of interfering waves and the resulting stripe patterns. The relative phases of each partial wave in space and time change the interference significantly and define the coherence of light - these concepts will be discussed in detail. We learn how to write and read phase information in holography.

6. Light Scattering and Plasmonics
The interaction of light with matter is based on particle scattering: we discuss the theoretical concepts of light scattering on the background of Fourier theory. We expend these approaches to photon diffusion, nonlinear optics, fluorescence and Raman scattering or scattering at semiconductor quantum dots - which are all hot topics in modern Photonics. A big emphasis is put on the description of surface plasmons and particle plasmons, where light can be extremely confined.

--- in Deutsch ---
Wir wissen nicht wirklich was Licht ist, obwohl die physkalischen Konzepte um Licht als Welle oder als Partikel zu beschreiben, sehr effizient funktionieren. Oft sind jedoch die quantitativen Beschreibungen von farbenvollen Intensitätsverteilungen, die wir alltäglich sehen können, recht kompliziert zu erfassen. Hierbei ist die Kontrolle von Licht, auf makroskopischer und nanoskaliger Ebene der Schlüssel zu eindrucksvollen Ergebnissen und Entdeckungen, die sowohl in der Wissenschaft als auch in der Industrie erzielt werden. In der Vorlesung „Wellenoptik“ werden wir theoretische Werkzeuge, wie beispielsweise die Fourier-Transformation, detailliert besprechen und auf diese Weise Schritt für Schritt ein tiefgründiges Verständnis der Wellenoptik erarbeiten. Die Vorlesung wird begleitet von vielen Experimenten und Übungen welche den Vorlesungsstoff vertiefen und in wöchentlichen Tutoraten besprochen werden.

1. Einleitung
Motivation, weiterführende Literatur und eine kleine Historie.

2. Von der elektromagnetischen Theorie zur Optik
Was ist Licht? Welches illustrative Bild zeichnen die Maxwell Gleichungen? Wenn dielektrische und metallische Materie als gedämpfte Federn beschrieben werden kann, wie ist der Zusammenhang zwischen Material und der Wellenlänge des einfallenden Lichts? Was sagen die Wellengleichung und die Helmholtz Gleichung aus? Wie können Wellen im Orts- und im Frequenzraum beschrieben werden?

3. Fourier-Optik
Wie verändert eine Welle eine Positionsinformation in eine Richtungsinformation? Was ist die Beziehung zur Fourier-Transformationen in 1D, 2D und 3D? Wie steht dies im Zusammenhang mit linearer optischer Systemtheorie, Raumfiltern und dem Abtasttheorem?

4. Wellenoptik, Lichtausbreitung und Beugung
Verschiedene Methoden werden vorgestellt wie die Lichtausbreitung im Orts- und im Frequenzraum beschrieben werden können. Wir stellen den direkten Transfer zwischen Lichtausbreitung und Beugung von Licht her. Wir behandeln evaneszente Wellen, dünne beugende Objekte, die Lichtausbreitung in inhomogenen Medien als auch die Impulserhaltung an optischen Gittern. Dies ermöglicht uns wichtige aktive optische Elemente wie zum Beispiel akusto-optische Modulatoren und SLMs zu diskutieren. Dieses Kapitel endet mit den Themen, adaptive Optik und Phasenkonjugation.

5. Interferenz, Kohärent und Holographie
Wir lernen wie die Komposition von k-Vektoren die Phase interferierender Wellen und die daraus resultierenden Streifenmuster definieren. Die relative Phase einer jeden Teilwelle in Raum und Zeit verändern hierbei die Interferenz signifikant und definieren die Kohärenz des Lichts; Diese Konzepte werden detailliert diskutiert. Wir lernen wie Phaseninformation mittels Holographie gelesen und geschrieben werden kann.

6. Lichtstreuung und Plasmonik

Die Interaktion von Licht mit Materie basiert auf der Partikel-Streuung: Wie diskutieren die theoretischen Konzepte der Lichtstreuung im Bezug auf die Fourier-Theorie. Wir erweitern diese Herangehensweise zur Photonendiffusion, nichtlinearer Optik, Fluoreszenz und Raman Streuung als auch Streuung an Halbleitern – alles brandaktuelle Themen in der modernen Photonik. Ein großer Schwerpunkt wird hierbei auf die Beschreibung von Oberflächenplasmonen und Partikelplasmonen gelegt. Hier kann Licht räumlich, extrem beschränkt werden.

1. Einleitung
1.1. Motivation
1.2. Literatur
1.3. Etwas Historie
2. Von der elektromagnetischen Theorie zur Optik
2.1. Was ist Licht?
2.2. Die Maxwell-Gleichungen
2.3. Die Veränderung von Licht in Materie
2.4. Wellengleichung & Helmholtzgleichung
2.5. Wellen im Orts- und Frequenzraum
3. Fourier-Optik
3.1. Einleitung
3.2. Die Fourier-Transformation
3.3. Linear-optische Systeme
3.4. Raumfilter
3.5. Das Sampling Theorem
4. Wellenoptische Lichtausbreitung und Beugung
4.1. Paraxiale Lichtausbreitung und Gauss-Strahlen
4.2. Wellenausbreitung und Beugung
4.3. Evaneszente Wellen
4.4. Beugung an dünnen Phasen- und Amplitudenobjekten
4.5. Lichtausbreitung in inhomogenen Medien
4.6. Beugung an gittern
4.7. Acousto-Optik
4.8. Spatiale Lichtmodulatoren
4.9. Adaptive Optik und Phasenkonjugation
5. Interferenz, Kohärenz und Holographie
5.1. Grundlagen
5.2. Interferometrie
5.3. Grundlagen der Kohärenz-Theorie
5.4. Prinzipien der Holographie
6. Lichtstreuung und Plasmonik
5.5. Streuung von Licht an Partikeln
5.6. Photonen Diffusion
5.7. Grundlagen nichtlinearer Optik
5.8. Fluoreszenz und Raman-Streuung
5.9. Fluoreszierende Quantum-Dots
5.10. Oberflächenplasmone and Partikelplasmone

Examination achievement
see module details
Course achievement
see module details
Literature
Lecture notes with defined voids (white boxes) will be provided.

Compulsory requirement
None
Recommended requirement
None

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Name of module	**Number of module**
Wave Optics	11LE50MO-5221 PO 2021
Veranstaltung	
Wave Optics	
Event type	Number
Übung	11LE50Ü-5221
Organizer	
Institut für Mikrosystemtechnik Bio- und Nano-Photonik	

ECTS-Points	
Hours of week	2.0
Recommended semester	4
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
During the exercise sessions the content of the lecture will be discussed in-depth and consolidated. In particular, students will be taught to transfer the acquired knowledge. The weekly exercise sheets have to be solved within a week and during the exercise sessions students will take turns in demonstrating their solutions on the blackboard, or - in the case of difficult assignments - the solution will be demonstrated by the tutor.
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Study Project in Concentration Photonics	11LE50MO-SP MSE PH
Responsible	
Prof. Dr.-Ing. Bastian Rapp	
Faculty	
Technische Fakultät	

ECTS-Points	9.0
Workload	270 Stunden /hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	unregelmäßig

Compulsory requirement
keine | none
Recommended requirement
allgemeine mathematische Grundlagen, praktische und theoretische Grundlagen der Ingenieurswissenschaften, Programmierkenntnisse, themenspezifische Vorkenntnisse für den gewählten Themenbereich | general fundamental mathematical knowledge, practical and theoretical foundations in Engineering Sciences, programming skills, subject-specific knowledge for the chosen topics

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload

Contents
In this module students get involved in the actual research process of the chosen work group/chair in the area of Photonics. Depending on their personal field of interest and their expertise in various research and teaching areas offered at the Department of Microsystems Engineering, they decide on a specific topic and deepen their knowledge and skills in this area as well as their overall proficiency in academic work and research. They learn to work on the different tasks required for the specific project under given technical specifications, to develop appropriate systems and to work experimentally and constructively in projects. Students acquire the ability to familiarize themselves with new engineering problems and do independent background research. They will work with modern development environments and adhere to the generally accepted quality standards. During the project, working in a team as well as observing the rules of good scientific work will be trained.
Qualification
Examination achievement
Depending on the specific project: written research paper or creation of demonstrators including a sufficient documentation or presentation and subsequent discussion

Course achievement
Regular attendance in (team) discussions or meetings with the supervisor. Self- organizing the given tasks, doing background research, presentation of results
Recommendation
Language is usually English, but might be negotiable (changed to German). Please learn about the procedure of finding a topic and registering for the project in good time. (For instance, see "A to Z - Study FAQ" under "Studies and Teaching" on our faculty website.)

↑

Name of module	**Number of module**
Seminar Integrated Photonics	11LE50MO-5721 PO 2021
Responsible	
Prof. Dr. Karsten Buse	
Organizer	
Institut für Mikrosystemtechnik Optische Systeme	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 Stunden | hours
Recommended semester	
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine | none
Recommended requirement
keine | none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Seminar Integrated Photonics	Seminar		3.0	2.0	

Qualification

- professional search of scientific and technical information
- assembly of a story for a presentation, considerding the targeted audience
- selection of informationen
- professional composition of viewgraphs
- successfull presentation and then also discussion of a scientific or technical topic
- writing of a one-page summary
- understanding of selected timely topics of integrated photonics

Examination achievement

mündlicher Vortrag / oral presentation

Course achievement

regelmäßige Teilnahme gemäß §13 (2) der Rahmenprüfungsordnung Master of Science/ regular attendance according to § 13 (2) of the framework examination regulations

Usability
As compulsory elective in ■ M.Sc. Embedded Systems Engineering (ESE) in Microsystems Engineering Concentrations Area: Photonics ■ M.Sc. Microsystems Engineering in Microsystems Engineering Concentrations Area: Photonics ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Photonik

↑

Name of module	**Number of module**
Seminar Integrated Photonics	11LE50MO-5721 PO 2021
Veranstaltung	
Seminar Integrated Photonics	
Event type	Number
Seminar	11LE50S-5721 PO 2021
Organizer	
Institut für Mikrosystemtechnik Optische Systeme	

ECTS-Points	3.0
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Topics from the area of integrated photonics will be provided for seminar talks. In a tutorial, an introduction to professional literature search and to the presentation of excellent talks will be given. Then individual support will be available for each talk: A starting package of literature will be provided. Assistance will be given for shaping a clear and convincing story and for selection of information that should make it into the speech. Then the viewgraphs will be made and commented. Finally, there will be the presentation, followed by a dicussion about the content and a second discussion, focussed onto the quality of the presentation itself. In addition, a one-page summary will be assembled, to be used as a hand-out.
Examination achievement
siehe Modulebene/see module details
Course achievement
siehe Modulebene/see module details
Literature
Will be provided for each talk individually.
Compulsory requirement

↑

Name of node	Number of node
Customized Course Selection	11LE50KO-WP-MSc-986-2021 CCS
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

↑

Name of node	Number of node
Courses offered by IMTEK	11LE50KO-WP-MSc-986-2021 KT 1
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

↑

Name of module	**Number of module**
Electrochemical energy applications: fuel cells and electrolysis	11LE50MO-5278 PO 2021
Responsible	
Prof. Dr.-Ing. Roland Zengerle	
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	
Faculty	
Technische Fakultät	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	in jedem Semester

Compulsory requirement
none
Recommended requirement
Knowledge in material science

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Electrochemical energy applications: fuel cells and electrolysis	Vorlesung		3.0	2.0	90 Stunden

Qualification
understanding/knowledge - basic electrochemistry - hydrogen fuel cell working principle, materials, systems - electrolysis working principle, materials, systems - redox flow batteries - electrochemical and ex-situ characterization methods
Examination achievement
Klausur, Dauer 90 Minuten|written exam, duration 90 minutes
Course achievement
keine

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	**Number of module**
Electrochemical energy applications: fuel cells and electrolysis	11LE50MO-5278 PO 2021
Veranstaltung	
Electrochemical energy applications: fuel cells and electrolysis	
Event type	Number
Vorlesung	11LE50V-5278
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	26
Independent study	64
Hours of week	2.0
Recommended semester	
Frequency	in jedem Semester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
none
Recommended requirement
Knowledge in material science

↑

Name of module	**Number of module**
Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers	11LE50MO-5719 PO 2021
Responsible	
Prof. Dr. Gerald Urban	
Organizer	
Institut für Mikrosystemtechnik Sensoren	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
Recommended requirement
▪ Introductory lecture to chemistry or similar knowledge ▪ Introductory lecture to electronics or similar knowledge

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers - Vorlesung	Vorlesung		3.0	2.0	90 hours

Qualification
The students know the essential concepts and fundamental equations of electrochemical theory. The participants from different subjects link together the knowledge from physical chemistry and several engineering disciplines to get a sound understanding of the classical electrochemical methods and electrochemical impedance spectroscopy. The students can apply their knowledge and understanding of the electrochemical methods to tasks in the field of material science, microtechnology, microsystems and energy application.
Examination achievement
written examination (90 minutes)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), Concentration Materials and Fabrication

↑

Name of module	Number of module
Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers	11LE50MO-5719 PO 2021
Veranstaltung	
Elektrochemische Methoden für Ingenieure / Electrochemical Methods for Engineers - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5719
Organizer	
Institut für Mikrosystemtechnik Sensoren Institut für Mikrosystemtechnik Elektr. Messt. u. Eingebettete Sys.	

ECTS-Points	3.0
Workload	90 hours
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Electrochemical theory (cells, electrodes, fundamental equation and concepts)
- Instrumentation (focus on the interplay between electrochemistry and electronics/data acquisition), equipment (electrodes, cells), and electrolytes
- Classical methods (potentiometry, amperometry, CV, DPV, SWV, HDME, RDE, RRDE)
- Electrochemical impedance spectroscopy (EIS)
- Selected aspects: Material science (corrosion, hierarchical micro-/nanostructures)
- Selected aspects: Microtechnology (electrodeposition, failure mechanism)
- Selected aspects: Microsystems (electrochemical sensors and actuators)
- Selected aspects: Energy application (fuel cells, batteries, super caps)

Examination achievement

see module details

Course achievement

none

Literature

- Bard, Faulkner: Electrochemical Methods – Fundamentals and Applications, 2nd ed., 2001, Wiley, library: SB/I.1/1
- Hamann, Hamnett, Vielstich: Electrochemistry, 2nd ed., Wiley-VCH 2007, library: SB/H.2/13
- Zoski: Handbook of electrochemistry, 1st ed., Elsevier, 2007, available as ebook (campus license)

Compulsory requirement

Recommended requirement
Introductory lecture to chemistry or similar knowledge Introductory lecture to electronics or similar knowledge

↑

Name of module	**Number of module**
Ergebnisse wissenschaftlich präsentieren / Scientific writing and presentation	11LE50MO-5801 PO 2021
Responsible	
Prof. Dr. Thomas Hanemann	
Organizer	
Institut für Mikrosystemtechnik Werkstoffprozesstechnik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden, 90 hours
Attendance	28 Stunden
Independent study	62 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	in jedem Semester

Compulsory requirement

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Ergebnisse wissenschaftlich präsentieren / Scientific writing and presentation - Seminar	Seminar		3.0	2.0	

Qualification
Die Studierenden werden ■ über die Bedeutung der Einhaltung der guten wissenschaftlichen Praxis informiert ■ in die Lage versetzt, ein Labortagebuch (Laborjournal) und einfache wissenschaftliche Berichte zu schreiben ■ über das Erstellen einer Master- bzw. Promotionsarbeit informiert ■ in die Lage versetzt, einen wissenschaftlichen Vortrag (15 min), einen Kurzvortrag (3 min), ein wissenschaftliches Poster sowie ein Werbeposter zu erstellen und zu präsentieren.

Examination achievement
In diesem Seminar wird der Ablauf und die Teilnahme an einer wissenschaftlichen Konferenz "simuliert". Die Studierenden müssen nach einer Inputphase durch den Lehrenden folgende Bestandteile während des Semesters erarbeiten und auf ILIAS hochladen: 1. Abstract (halbe Seite) 2. 15 min Vortrag 3. 3 min Kurzvortrag 4. Wissenschaftliches Poster 5. Poster für einen Tag der offenen Tür 6. 6 Seiten Paper Inhaltlich dürfen die Teilnehmenden ihre jeweilige Bachelorarbeit verwenden. Die Vorträge und die Poster werden in der Gruppe präsentiert, diskutiert und anschließend gibt es ein Feedback durch die Gruppe und den Lehrenden. Am Ende werden nach einem Gewichtungsschlüssel die Einzelbeiträge zu einer Note zusammengefasst.| In this seminar, the process and participation in a scientific conference is "simulated". After an input phase by the lecturer, students have to work on the following components during the semester and upload them on ILIAS: 1. abstract (half a page) 2. 15 min presentation 3. 3 min short presentation 4. scientific poster 5. poster for an open day 6. 6 page paper In terms of content, participants are allowed to use their respective bachelor theses. The presentations and the posters will be presented and discussed in the group and afterwards there will be a feedback by the group and the lecturer. The final grade is calculated by combining the individual components according to their respective weight.
Course achievement
keine/none
Usability
Wahlmodul für Studierende des Studiengangs ■ Bachelor of Science im Fach Embedded Systems Engineering ■ Master of Science im Fach Informatik - Fachfremdes Wahlmodul Mikrosystemtechnik ■ Master of Science im Fach Embedded Systems Engineering - Personal Profile ■ Master of Science im Fach Mikrosystemtechnik - Personal Profile ■ Master of Science im Fach Microsystems Engineering - Personal Profile

↑

Name of module	Number of module
Ergebnisse wissenschaftlich präsentieren / Scientific writing and presentation	11LE50MO-5801 PO 2021
Veranstaltung	
Ergebnisse wissenschaftlich präsentieren / Scientific writing and presentation - Seminar	
Event type	Number
Seminar	11LE50S-5801

ECTS-Points	3.0
Attendance	28 Stunden
Hours of week	2.0
Recommended semester	4
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

The following topics will be covered during the course:
- Ancient and current scientific malpractice
- Rules for safeguarding good scientific practice
- Laboratory journal, Scientific reports (from project reports to dissertation thesis)
- Lecture presentation
- Oral poster presentation (3 minutes lecture)
- Scientic poster presentation, "Advertisement" poster

Examination achievement

see module details

Course achievement

see module details

Literature

- C. Ascheron, Die Kunst des wissenschaftlichen Präsentierens und Publizierens, Elsevier, München, 2007, ISBN-13: 978-3-8274-1741-1
- H.F. Ebel, C. Bliefert, W.E. Russey, The Art of Scientific Writing, Wiley-VCH, Weinheim, 2004, ISBN: 978-3-527-29829-7

Compulsory requirement

Teaching method

In the summer semester in German, in the winter semester in English.

↑

Name of module	**Number of module**
Machine Learning	11LE13MO-1153 PO 2021
Responsible	
Prof. Dr. Joschka Bödecker Prof. Dr. Frank Roman Hutter	
Organizer	
Institut für Informatik Neurorobotik Institut für Informatik Maschinelles Lernen	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden | hours
Recommended semester	1
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
keine | none
Recommended requirement
We have to rely on a solid background in basic math, specifically linear algebra (an eigenvalue decomposition, matrix operations, covariance matrices etc. should be very familiar concepts), calculus and probability theory. We use the Python programming language for most of our assigments. If you do not yet have Python experience, you must ramp up at least basic knowledge thereof. We recommend basic knowledge of optimization and of the scikit-learn Python library.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Machine Learning	Vorlesung		6.0	3.0	180 Stunden | hours
Machine Learning	Übung			1.0	

Qualification
This course provides you with a good theoretical understanding and practical experience about the basic concepts of machine learning. You shall be enabled to implement a number of basic algorithms, understand advantages and drawbacks of single methods and know typical application domains thereof. Furthermore, you should be able to use (Python) software libraries in order to work on novel data analysis problems.

The course will prepare you to dive deeper into advanced methods of ML, e.g. deep learning, recurrent networks, reinforcement learning, hyperparameter optimization, and into specific application domains such as image analysis, brain signal analysis, robot learning, bioinformatics etc., for which specialized courses are available.
Examination achievement
Ususally a written exam (duration of 90 to 180 minutes) If the number of participants is small, an oral examination (with a duration of 35 minutes) may be held instead. The students will be informed in good time.
Course achievement
To prepare for the exam, there can be a mock exam (written or oral).
Usability
Wahlpflichtmodul für Studierende des Studiengangs ■ B.Sc. in Embedded Systems Engineering (PO 2018) im Bereich Informatik ■ B.Sc. in Informatik (PO 2018) ■ polyvalenter 2-Hauptfächer-Bachelor Informatik (PO 2018) ■ M.Ed. Informatik (PO 2018) ■ Master of Education Erweiterungsfach Informatik (PO 2021) Compulsory elective module for students of the study program ■ M.Sc. Informatik / Computer Science (2020) in Weiterführende Vorlesung | Advanced Lectures ■ M.Sc. Embedded Systems Engineering (ESE) (2021) in Essential Lectures in Computer Science ■ Students of the M.Sc. programs Microsystems Engg. and Mikrosystemtechnik (PO 2021) can select this module in the concentration area Biomedical Engineering (Biomedizinische Technik). Teil der Spezialisierung Künstliche Intelligenz im Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering| Part of the specialization Artificial Intelligence in Master of Science Informatik/Computer Science bzw. MSc Embedded Systems Engineering

↑

Name of module	**Number of module**
Machine Learning	11LE13MO-1153 PO 2021
Veranstaltung	
Machine Learning	
Event type	Number
Vorlesung	11LE13V-1153
Organizer	
Institut für Informatik Maschinelles Lernen	

ECTS-Points	6.0
Workload	180 Stunden | hours
Attendance	45 Stunden | hours
Independent study	120 Stunden | hours
Hours of week	3.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

- Applications / typical problems dealt with by machine learning
- basic data analysis pipeline (from data recording to output shaping)
- software libraries
- linear methods (e.g. LDA, logistic regression, ICA, PCA, OLSR) for dimensionality reduction, classification, regression and blind source separation
- non-linear methods (e.g. support vector machines, kernel PCA, decision trees / random forests, neural networks) for classification and regression
- unsupervised clustering (e.g. k-means, DBSCAN)
- algorithm independent principles in machine learning (z.b. bias-variance trade-off, model complexity, regularization, validation strategies, interpretation of trained machine learning models, basic optimization approaches, feature selection, data visualization)

Examination achievement

Siehe Modulebene |
See module level

Course achievement

Siehe Modulebene |
See module level

Literature

Duda, Hart and Stork: Pattern Classification
Christopher Bishop: Pattern Recognition and Machine Learning
Hastie, Tibshirani and Friedman: The Elements of Statistical Learning
Mitchell: Machine Learning
Murphy: Machine Learning – a Probabilistic Perspective
Criminisi et. al: Decision Forests for Computer Vision and Medical Image Analysis
Schölkopf & Smola: Learning with Kernels

Goodfellow, Bengio and Courville: Deep Learning Michael Nielsen: Neural Networks and Deep Learning In addition, literature for every section of the course is announced during these sections.
Compulsory requirement
keine | none
Recommended requirement
We have to rely on a solid background in basic math, specifically linear algebra (an eigenvalue decomposition, matrix operations, covariance matrices etc. should be very familiar concepts), calculus and probability theory. We use the Python programming language for most of our assigments. If you do not yet have Python experience, you must ramp up at least basic knowledge thereof. We recommend basic knowledge of optimization and of the scikit-learn Python library.
Teaching method
For in-class lectures: Despite the large lecture rooms, a teacher-centered style shall be enriched as much as possible by measures like: ■ interactive question and answer rounds ■ discussions in sub-groups, reporting to the large group ■ cross-teaching ■ problem-oriented teaching e.g. via data analysis competition ■ repetition of important concepts in slightly altered contexts. **For virtual lectures:** ■ flipped classroom teaching with videos provided ■ Q&A sessions to discuss the videos' content ■ Cross-teaching via Ilias forum ■ problem-oriented teaching e.g. via data analysis competition ■ repetition of important concepts in slightly altered contexts.

↑

Name of module	**Number of module**
Machine Learning	11LE13MO-1153 PO 2021
Veranstaltung	
Machine Learning	
Event type	Number
Übung	11LE13Ü-1153
Organizer	
Institut für Informatik Maschinelles Lernen	

ECTS-Points	
Attendance	15 Stunden | hours
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The exercises are intended to give students a better understanding of the most important techniques they learn during lectures. They are expected to implement some selected methods to gain experience in practical applications.
Examination achievement
Siehe Modulebene | See module level
Course achievement
Siehe Modulebene | See module level
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	**Number of module**
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	11LE50MO-5263 PO 2021
Responsible	
Prof. Dr.-Ing. Roland Zengerle	
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
Basics in microfluidics, e.g. "Microfluidics I"

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	Vorlesung		6.0	2.0	180 hours
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	Übung			2.0	

Qualification
Qualified microfluidic engineer with sound knowledge on microfluidic Design, manufacturing of microfluidic cartridges, and the use of microfluidic technologies in clinical settings.
Examination achievement
Ususally a written exam (duration of 90 to 180 minutes) If the number of participants is small, an oral examination (with a duration of 35 minutes) may be held instead. The students will be informed in good time.
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	11LE50MO-5263 PO 2021
Veranstaltung	
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	
Event type	Number
Vorlesung	11LE50V-5263
Organizer	
Institut für Mikrosystemtechnik Anwendungsentwicklung	

ECTS-Points	6.0
Workload	180 hours
Attendance	60
Independent study	120
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Content: This lecture teaches the use of microfluidic technologies for automation of biochemical analyses. Fields of application are the detection of pathogens, the diagnosis and therapy accompanied monitoring of tumor diseases as well as water analysis. In a first section, the complete design process from initial requirements and project specifications to simulation-based design, manufacturing of functional models and testing will be addressed. The creation of flow drafts, the simulation of microfluidic networks and CAD design will be taught in an accompanying tutorial. In following lectures, product development will be examined. This includes the scalable manufacturing of disposable test cartridges, the determination of usability as well as questions of licensing. In summary, the lecture covers the development process from initial idea to product. In the second part of the tutorial, the students will work on an exemplary project.
Examination achievement
see module details
Course achievement
none
Compulsory requirement
none
Recommended requirement
Basics of microfluidics, e.g. Microfluidics I lecture

↑

Name of module	**Number of module**
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	11LE50MO-5263 PO 2021
Veranstaltung	
Mikrofluidik II: Miniaturisieren, Automatisieren, und Parallelisieren biochemischer Analyseverfahren: Von der Idee zum Produkt	
Event type	Number
Übung	11LE50Ü-5263
Organizer	
Technische Fakultät Institut für Mikrosystemtechnik Anwendungsentwicklung	

ECTS-Points	
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
none
Compulsory requirement
none
Recommended requirement
none

↑

Name of module	Number of module
Projektmanagement für Ingenieure / Project management for engineers	11LE50MO-5803 PO 2021
Responsible	
Prof. Dr.-Ing. Ulrike Wallrabe	
Organizer	
Institut für Mikrosystemtechnik Mikroaktorik	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	28 oder 32 Stunden
Independent study	58 oder 62 Stunden
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	in jedem Semester

Compulsory requirement

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Projektmanagement für Ingenieure / Project management for engineers - Seminar	Seminar			2.0	

Qualification
Students shall learn the basic ideas and techniques of project management and apply them to representative examples. They shall realize that planning tasks isn't always as clear-cut as in engineer courses. A project can be structured in different ways. One plan isn't necessarily better than the other. Instead, one approach might be more practical or provide a better overview than another. Additionally, the students shall gain insight into the soft skills of project management, i.e. how to deal with operating persons, namely the project team as a social system.
Examination achievement
Klausur (Dauer 90 Minuten) |written exam (duration 90 minutes)
Course achievement
keine/none
Grading
Die Modulnote errechnet sich zu 100% aus der schriftlichen oder mündlichen Abschlussprüfung.

Examination weight
■ Bachelor of Science im Fach Embedded Systems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet. ■ Bachelor of Science im Fach Embedded Systems Engineering Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten dreifach gewichtet in die Gesamtnote eingerechnet. ■ Master of Science im Fach Embedded Systems Engineering Prüfungsordnungsversion 2012: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. ■ Master of Science im Fach Informatik, Prüfungsordnungsversion 2005: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. ■ Master of Science im Fach Informatik, Prüfungsordnungsversion 2011: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. ■ Master of Science im Fach Microsystems Engineering, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet. ■ Master of Science im Fach Mikrosystemtechnik, Prüfungsordnungsversion 2009: Die Modulnote wird nach ECTS-Punkten einfach gewichtet in die Gesamtnote eingerechnet.
Recommendation
WS: English, SS: German
Usability
Wahlmodul für Studierende des Studiengangs ■ Bachelor of Science im Fach Embedded Systems Engineering ■ Master of Science im Fach Informatik - Fachfremdes Wahlmodul Mikrosystemtechnik ■ Master of Science im Fach Embedded Systems Engineering - Personal Profile ■ Master of Science im Fach Mikrosystemtechnik - Personal Profile ■ -PO 2021: Individuelle Ergänzung ■ Master of Science im Fach Microsystems Engineering - Personal Profile ■ - PO 2021: Customized Course Selection

↑

Name of module	Number of module
Projektmanagement für Ingenieure / Project management for engineers	11LE50MO-5803 PO 2021
Veranstaltung	
Projektmanagement für Ingenieure / Project management for engineers - Seminar	
Event type	Number
Seminar	11LE50P-5803
Organizer	
Institut für Mikrosystemtechnik Mikroaktorik	

ECTS-Points	
Attendance	28 oder 32 Stunden
Hours of week	2.0
Recommended semester	4
Frequency	in jedem Semester
Pflicht/Wahlpflicht (P/WP)	

Contents
The course comprises a mixture of lecture and group work with short presentations of the obtained project plans. The different phases of a project and its respective project management, i.e. project assignment, planning, execution and completion of a project, is presented as an introduction into the field. The different roles of people coping with the project, i.e. initiator or customer, project manager and staff, and their duties are presented, and their responsibilities analysed. Various planning techniques and plans will be introduced: project environment analysis, risk analysis, work breakdown structure, Gantt chart and SWOT analysis. The financial budgeting of a project will be shown: existing cost factors, their estimation and what exactly has to be considered. In addition, the more technical aspect of project planning will be supplemented with soft skills, like how to lead a discussion, mediation, etc. MS Project will be used to make the project management simpler. With its help project plans for fictitious projects will be developed. The presented lecture content will be visualized with two fictitious projects. The students will have to implement the learning matter in individual and team work. The projects are a journey round the world with fellow students after graduation and a virtual Master thesis.
Examination achievement
Course achievement
Literature
Regularly updated lecture notes are available.
Compulsory requirement

Teaching method
This course is offered in English in the winter semester, in German in the summer semester.

↑

Name of module	**Number of module**
Neuroprothetik / Neuroprosthetics	11LE50MO-5318 PO 2021
Responsible	
Prof. Dr. Ulrich Hofmann	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
None
Recommended requirement
High school level knowledge in mathematics and natural sciences

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Neuroprothetik / Neuroprosthetics - Seminar	Seminar		3.0	3.0	90 hours

Qualification
In times of an explosion of so called bioelectronic medicine remedies, aka electroceuticals, engineering students will gain an introductory knowledge of neuroscientific basics, a profound knowledge of technical interfaces to the brain and a wide view on diseases presumbaly treated by these devices. In particular, they will investigate the pathes from bench to bedside bringing medical devices into clinical use. In the end, they will be able to critically assess business models of startups in the field of bioelectronic medicine.
Examination achievement
Written documentation in the form of a short scientific paper (5-10 pages) and oral presentation. The module grade is based on the written documentation (50%) and the oral presentation (50%).
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Neuroprothetik / Neuroprosthetics	11LE50MO-5318 PO 2021
Veranstaltung	
Neuroprothetik / Neuroprosthetics - Seminar	
Event type	Number
Seminar	04LE50V-5318

ECTS-Points	3.0
Workload	90 hours
Attendance	39 hours
Independent study	51 hours
Hours of week	3.0
Recommended semester	5
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

Introductory lessons contain:
- Basic concepts of neuroscience
- Interfacing the nervous system
- Modelling approaches for CNS applications
- Neuroethical aspects

Student covered topics will contain:
- Cochlea Implant - Deafness
- Retina Implant - Blindness
- Deep Brain Stimulation - Parkinson‘s Disease
- Spinal Cord Stimulation - Chronic Pain Syndrome
- Vagal Nerve Stimulation - Epilepsy
- Functional Electrical Stimulation - Drop Foot Syndrome
- Human Machine Interfacing - BCI and BMI
- Foreign Body Reaction

Examination achievement

see module details

Course achievement

None

Literature

- Farina, D., Jensen, W., Akay, M., Eds. (2013). INTRODUCTION TO NEURAL ENGINEERING FOR MOTOR REHABILITATION, IEEE
- Dagnelie, G., Ed. (2011). Visual Prosthetics: Physiology, Bioengineering, Rehabilitation: Physiology, Bioengineering and Rehabilitation, Springer
- DiLorenzo, D. J. and J. D. Bronzino, Eds. (2008). Neuroengineering Boca Raton, CRC Press
- Akay, M. (2007). Handbook of Neural Engineering, IEEE Press, Wiley
- Dornhege, G., et al., Eds. (2007). Toward Brain-Computer Interfacing. Neural Information Processing Series. Cambridge, MA, MIT Press

■ Horch, K. W. and G. S. Dhillon (2004). Neuroprosthetics - Theory and Practice. Singapore-London, World Scientific Publishing
Compulsory requirement
None
Recommended requirement
High level knowledge in mathematics and natural sciences

↑

Name of module	**Number of module**
Soft Robotics	11LE50MO-5374 PO 2021
Responsible	
JProf. Dr. Edoardo Milana	
Organizer	
Institut für Mikrosystemtechnik Professur für Soft Machines	
Faculty	
Technische Fakultät	

ECTS-Points	6.0
Workload	180 Stunden/hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none
Recommended requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Soft Robotics	Vorlesung		6.0	2.0	180 hours
Soft Robotics - Projekt	Projekt			2.0	

Qualification
The objective of this course it to provide students of engineering with the basics of Soft Robotics. Thus, the following topics will be addressed: - design and modeling of soft robots - soft actuation principles - materials and fabrication processes - control of soft robots - multifunctional embodiement
Examination achievement
oral examination oral presentation The final grade will be a weighted average of the project presentation (30%) and oral exam (70%)
Course achievement
none

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication ■ M.Sc. Informatik / Computer Science (PO 2020), in Spezialvorlesung | Specialization Courses Wahlpflichtmodul für Studierende des Studiengangs ■ Master of Science in Sustainable Systems Engineering - Interdisciplinary Profile

↑

Name of module	Number of module
Soft Robotics	11LE50MO-5374 PO 2021
Veranstaltung	
Soft Robotics	
Event type	Number
Vorlesung	11LE50V-5374
Organizer	
Institut für Mikrosystemtechnik Professur für Soft Machines	

ECTS-Points	6.0
Workload	180 hours
Hours of week	2.0
Recommended semester	3
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
The students will learn how to design, fabricate and control robots made of soft and deformable materials. Models of soft manipulators based on beam theory and piecewise constant strain approximation will be introduced. We will study the main soft actuation mechanisms, such as inflatable actuators, electroactive polymers, magnetorheological elastomers, liquid crystal elastomers. Different manufacturing techniques will be analysed, in the context of polymer molding and additive manufacturing. Further, we will see some examples of model-based control for soft robots. Finally, the concept of multifunctional embodiement of sensing, actuation, control and energy will be discussed. During the course there will be a project assignment, where the students will be divided in groups and will be given a design challenge for a soft robotic system with specific requirements in terms of operational environment and locomotion modes.
Examination achievement
See module level
Course achievement
See module level
Literature
Della Santina, Cosimo, et al. "Soft robots." Encyclopedia of Robotics 489 (2020). Rus, Daniela, and Michael T. Tolley. "Design, fabrication and control of soft robots." Nature 521.7553 (2015): 467-475. Gorissen, Benjamin, et al. "Elastic inflatable actuators for soft robotic applications." Advanced Materials 29.43 (2017): 1604977. Suzumori et al "The Science of Soft Robots: Design, Materials and Information Processing", Springer (2023)
Compulsory requirement
None
Recommended requirement
Continuum Mechanics (Solid and Fluid), Electromagnetism, Thermodynamics

↑

Name of module	**Number of module**
Soft Robotics	11LE50MO-5374 PO 2021
Veranstaltung	
Soft Robotics - Projekt	
Event type	Number
Projekt	11LE50P-5374
Organizer	
Institut für Mikrosystemtechnik Professur für Soft Machines	

ECTS-Points	
Hours of week	2.0
Recommended semester	3
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
See module level
Course achievement
See module level
Compulsory requirement

↑

Name of module	**Number of module**
Techniken zur Oberflächenmodifizierung / Surface coating Techniques	11LE50MO-5109 PO 2021
Responsible	
Prof. Dr. Jürgen Rühe	
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	
Faculty	
Technische Fakultät Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 Stunden
Recommended semester	3
Duration	
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
none

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Techniken zur Oberflächenmodifizierung / Surface coating Techniques	Vorlesung		3.0	2.0	90 Stunden

Qualification
This module describes all aspects of surface modification as often used in microsystems engineering. It tackles questions on the chemistry of the various approaches and discusses the advantages and shortcomings of a number of methods. Among the techniques presented are high energy surface oxidation techniques (chemical modification, flame treatment, corona discharge or plasma) as well as more elaborate approaches such as sef-assembled monolayers. Special emphasis is given to the use of polymers for coartings.
Examination achievement
Schriftliche Abschlussprüfung (Klausur) mit einer Dauer von 90 Minuten
Course achievement
keine

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Materials and Fabrication ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Materialien und Herstellungsprozesse ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Materials and Fabrication

↑

Name of module	**Number of module**
Techniken zur Oberflächenmodifizierung / Surface coating Techniques	11LE50MO-5109 PO 2021
Veranstaltung	
Techniken zur Oberflächenmodifizierung / Surface coating Techniques	
Event type	Number
Vorlesung	11LE50V-5109
Organizer	
Institut für Mikrosystemtechnik Chemie und Physik von Grenzflächen	

ECTS-Points	3.0
Workload	90 Stunden
Attendance	30
Independent study	60
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Among the techniques presented are high energy surface oxidation techniques (chemical modification, flame treatment, corona discharge or plasma) as well as more elaborate approaches such as self-assembled monolayers. Special emphasis is given to the use of polymers for coatings and techniques will be described that yield surface attached polymer monolayers and multilayer assemblies. Examples from current research topics will be discussed.
Examination achievement
siehe Modulebene
Course achievement
keine
Compulsory requirement
none

↑

Name of module	**Number of module**
Technologien der Implantatfertigung / Implant Manufacturing Technologies	11LE50MO-5313 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	3
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Wintersemester

Compulsory requirement
None
Recommended requirement
None

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Vorlesung	Vorlesung		3.0	2.0	90 hours
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Übung	Übung			1.0	

Qualification
The aim of the module is to teach the physical and technological fundamentals for manufacturing electrically active implants, to become familiar with basic structures and elements as well as methods and processes for their manufacture. The theoretical engineering basis for understanding the function and failure modes of this type of implants is provided. The module teaches students of microsystems engineering the various, basic processes on the basis of which complex implants can be realized. The exercise supplements the theoretical knowledge with practical aspects and guides the independent application of the knowledge gained.
Examination achievement
Written examination (90 minutes)

Course achievement
none
Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	Number of module
Technologien der Implantatfertigung / Implant Manufacturing Technologies	11LE50MO-5313 PO 2021
Veranstaltung	
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Vorlesung	
Event type	Number
Vorlesung	11LE50V-5313
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	45 hours
Independent study	45 hours
Hours of week	2.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents

In the lecture Implant Manufacturing Technologies, knowledge and methods for the development of electrically active implants such as pacemakers or hearing prostheses (cochlear implants) are taught. Materials, components, systems and legal frameworks are presented. Clinically established (neuro-) implants as well as novel developments, which are still in the research phase, will be presented and critically discussed. The following topics will be covered during the lecture:

- Overview of active implants & neuroprostheses in clinical and research settings.
- Definitions and classification of electrically active implants
- Biocompatibility testing and biostability (corrosion and degradation)
- Electrodes
- Design of electrically active implants (components, interfaces)
- Silicone as material for encapsulation
- Materials for hermetically sealed housings
- Connections and joining techniques
- Requirements for implant development and production (risk management, FMEA, production rooms, documentation)
- Thin-film technology in implant development
- Manufacturing of microimplants using the example of a BION

Finally, the learning content will be repeated together with the students in order to facilitate the preparation for the examination.

Examination achievement

see module details

Course achievement

None

Compulsory requirement
None
Recommended requirement
None

↑

Name of module	**Number of module**
Technologien der Implantatfertigung / Implant Manufacturing Technologies	11LE50MO-5313 PO 2021
Veranstaltung	
Technologien der Implantatfertigung / Implant Manufacturing Technologies - Übung	
Event type	Number
Übung	11LE50Ü-5313
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	
Hours of week	1.0
Recommended semester	
Frequency	nur im Wintersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
see module details
Course achievement
none
Compulsory requirement

↑

Name of module	**Number of module**
Technologien der Implantatfertigung - Praktikum / Implant Manufacturing Technologies - Laboratory	11LE50MO-5314 PO 2021
Responsible	
Prof. Dr.-Ing. Thomas Stieglitz	
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	
Faculty	
Institut für Mikrosystemtechnik	

ECTS-Points	3.0
Workload	90 hours
Recommended semester	2
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Wahlpflicht
Frequency	nur im Sommersemester

Compulsory requirement
Successful completion of the module "Technologien der Implantfertigung / Implant manufacturing technologies".
Recommended requirement
Basic knowledge in mathematics and sciences.

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
Technologien der Implantatfertigung - Praktikum / Implant Manufacturing Laboratory	Praktikum		3.0	4.0	90 hours

Qualification
The aim of the module is to train the skills for manufacturing electrically active implants, to become familiar with basic structures and elements as well as methods and processes for their manufacture. The theoretical engineering basis for understanding the function and failure modes of this type of implants is complemented by practical skills and experience during own manufacturing of a demonstrator of an active implant.
Examination achievement
Written test prior to each of the seven experiments. The module grade is the average of the marks obtained in the seven tests.
Course achievement
Mandatory attendance in the 12 sessions is required. In case of illness, an additional session is offered.

Usability
Compulsory elective module for students of the study program ■ M.Sc. Microsystems Engineering (PO 2021), Concentration Biomedical Engineering ■ M.Sc. Mikrosystemtechnik (PO 2021), Vertiefung Biomedizinische Technik ■ M.Sc. Embedded Systems Engineering (PO 2021), in Microsystems Engineering Concentrations Area: Biomedical Engineering

↑

Name of module	**Number of module**
Technologien der Implantatfertigung - Praktikum / Implant Manufacturing Technologies - Laboratory	11LE50MO-5314 PO 2021
Veranstaltung	
Technologien der Implantatfertigung - Praktikum / Implant Manufacturing Laboratory	
Event type	Number
Praktikum	11LE50P-5314
Organizer	
Institut für Mikrosystemtechnik Biomedizinische Mikrotechnik	

ECTS-Points	3.0
Workload	90 hours
Attendance	52 hours
Independent study	38 hours
Hours of week	4.0
Recommended semester	
Frequency	nur im Sommersemester
Pflicht/Wahlpflicht (P/WP)	

Contents
In the course of the practical exercises, the students re-build the first generation of a neuroptosthetic device, a cochlear implant. Groups with a maximum of three persons manufacture the implant in structured learning units on their own under supervision at different manufacturing setups. The learning units include: ■ Laser marking and cutting ■ Screen printing ■ Hybrid implant assembly ■ Design of pronted circuit boards ■ Development and etching of printed circuit boards ■ Cleansing and cleaning of substrates ■ Silicone encapsulation or electronic circuits ■ Packaging and sterilization ■ Technical implant function test
Examination achievement
see module details
Course achievement
see module details
Compulsory requirement
Successful completion of the module "Technologien der Implantfertigung / Implant manufacturing technologies".
Recommended requirement
Basic knowledge in mathematics and sciences.

↑

Name of node	Number of node
Courses offered by other departmens of the University of Freiburg	11LE50KO-WP-MSc-986-2021 KT 2
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

↑

Name of module	**Number of module**
High-throughput data analysis with Galaxy	11LE50MO-1342
Responsible	
Faculty	
Technische Fakultät	

ECTS-Points	
Workload	
Recommended semester	
Duration	1 Semester
Pflicht/Wahlpflicht (P/WP)	Pflicht
Frequency	nur im Sommersemester

Compulsory requirement

Assigned Courses					
Name	Type	P/WP	ECTS	HoW	Workload
			6.0		

Qualification

↑

Name of module	**Number of module**
High-throughput data analysis with Galaxy	11LE50MO-1342

High-throughput data analysis with Galaxy
Event type

ECTS-Points	
Hours of week	
Recommended semester	
Frequency	
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	Number of module
High-throughput data analysis with Galaxy	11LE50MO-1342
High-throughput data analysis with Galaxy	
Event type	

ECTS-Points	6.0
Hours of week	
Recommended semester	2
Frequency	
Pflicht/Wahlpflicht (P/WP)	

Contents
Examination achievement
Course achievement
Compulsory requirement

↑

Name of module	**Number of module**
High-throughput data analysis with Galaxy	11LE50MO-1342
Name of Non-graded work	
Exam type	Number
Responsible	
Faculty	

Exam form	
Grading	
Compulsory	

↑

Name of node	**Number of node**
Language courses	11LE50KO-WP-MSc-986-2021 KT 3
Faculty	
Technische Fakultät	

Pflicht/Wahlpflicht (P/WP)	Pflicht

Comment
In this area, international students may complete one or two German language courses. The maximum amount of ECTS points that can be collected in this area is 9. German students may complete one or two English language courses.

↑

Epilogue

EDITION NOTICE

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