Description of Module Master of Science
628 Photonics
PO-Version 2013

FRIEDRICH-SCHILLER-UNIVERSITÄT JENA

Contents summary

Note : Please note that you can find the information on examinations, courses corresponding to the examinations, and examination dates in the portal Friedolin under the menu item ‘Browse module descriptions’. After logging in, please choose your degree, your study programme, and respective module. Any immediate changes made will be displayed promptly.

Modul **PAFMF003** Solid State Optics	
Module code	PAFMF003
Module title (German)	Solid State Optics
Module title (English)	Solid State Optics
Person responsible for the module	Prof. Dr. H. Schmidt
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Solid state physics / Material science” or ”Optics” Required electrive module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	2 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecutre: 2 h per week Exercise: 1 h per week
ECTS credits	8 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	240 h 90 h 150 h
Content	• Electronic, dielectric, and optical properties of solids; • Mueller matrix polarimetry; • Electrooptics and magnetooptics; • Photodetectors and optical systems; • Quantum optics and quantum technologies.
Intended learning outcomes	The course covers basic and advanced topics of solid state optics, with a special focus on the relation between electronic and optical properties. An effort is made to treat electro- and magnetooptical effects and quantum optical effects as rigorous as possible through the Mueller matrix approach and through quantum mechanical approaches, respectively.
Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester.
Requirements for awarding credit points (type of examination)	Module examination written or oral summer semester (50%) Module examination written or oral winter semester (50%)
Language of instruction	English

Modul **PAFMF009** Optoelectronics	
Module code	PAFMF009
Module title (German)	Optoelektronik
Module title (English)	Optoelectronics
Person responsible for the module	Apl. Prof. Dr. F. Schmidl
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Solid state physics / Material science” and ”Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Semiconductors • Optoelectronic devices • Photodiodes • Light emitting diodes • Semiconductor optical amplifier
Intended learning outcomes	In this course the student will learn the fundamentals of semiconductor optical devices such as photodiodes, solar cells, LEDs, laser diodes and semiconductor optical amplifiers.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMF018** Quantum Information Theory	
Module code	PAFMF018
Module title (German)	Quanteninformationstheorie
Module title (English)	Quantum Information Theory
Person responsible for the module	Prof. A. Tünnermann Dr. F. Steinlechner Dr. F. Eilenberger (PD Dr. W. Krech)
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Solid state physics / Material science" or " Gravitation and Quantum Theory" Required elective module B.Sc. Physics
Frequency of offer (how often is the module offered?)	At irregular intervals
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	Lecture of Drs. Eilenberger, Steinlechner • Basic introduction to quantum optics; • Quantum light sources; • Encoding, • transmission and detection of information with quantum light; • Quantum communication and cryptography; • Quantum communication networks; • Outlook on Quantum metrology and Quantum imaging; Lecture of PD Krech • Qubit • Quantum entropy of information • Quantum data compression • Hidden quantum information / non-locality • Bell's inequalities

Intended learning outcomes	The course will give a basic introduction into the usage of quantum states of light for the exchange of information. It will introduce contemporary methods for the generation of quantum light and schemes that leverage these states for the exchange of information, rangingfrom fundamental concepts and experiments to state of the artimplementations for secure communication networks. The course willalso give an outlook to aspects of Quantum metrology and imaging.Afteractive participation in the course, the students will be familiarwith the basic concepts and phenomena of quantum information exchangeand some aspects related to the practical implementation thereof.They will be able to apply their knowledge in the assessment andsetup of experiments and devices for applications of quantuminformation processing.
Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester.
Requirements for awarding credit points (type of examination)	Written or oral examination or presenation (100%) The form of the exam will be announced at the beginning of the semester.
Recommended reading	• Grynberg / Aspect / Fabre "Introduction to Quantum Optics"; • Body ”Nonlinear Optics”;Kok / Lovett ”Introduction to Optical Quantum Information Processing”; • Leuchs ”Lectures on Quantum Information”;Sergienko ”Quantum Communications and Cryptograhy”; • Ou / Jeff ”Multi-Photon Quantum Interference”;
Language of instruction	English (Drs. Eilenberger, Steinlechner) Geman (PD Krech)

Modul **PAFMO001** Fundamentals of Modern Optics	
Module code	PAFMO001
Module title (German)	Fundamentals of Modern Optics
Module title (English)	Fundamentals of Modern Optics
Person responsible for the module	Prof. Dr. Thomas Pertsch
Prerequisites for admission to the module	None
Type of module (compulsory module, required elective module, elective module)	Compulsory Module
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 4 h per week Exercise: 2 h per week
ECTS credits	8 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	240 h 90 h 150 h
Content	• Basic concepts pf wave optics • Dielectric function to describe light-matter interaction • Propagation of beams and pulses • Diffraction theory • Elements of Fourier optics • Polarization of light • Light in structured media • Optics in crystals
Intended learning outcomes	The course covers the fundamentals of modern optics which are necessary for the understanding of optical phenomena in modern science and technology. The students will acquire a thorough knowledge of the most important concepts of modern optics. At the same time the importance and beauty of optics in nature and in technology will be taught. This will enable students to follow more specialized courses in photonics.
Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester.
Requirements for awarding credit points (type of examination)	Written examination (100%)

Recommended reading	• B.E.A. Saleh and M.C. Teich, ”Fundamentals of Photonics,” Wiley (2007). • H. Lipson, D.S. Tannhauser, S.G. Lipson, ”Optical Physics,” Cambridge (2010). • E. Hecht and A. Zajac, ”Optics,” Addison-Wesley Longman (2003). • F.L. Pedrotti, L.S. Pedrotti, L.M. Pedrotti, ”Introduction to Optics,” Pearson (2006) • G. Brooker, ”Modern Classical Optics,” Oxford (2002).
Language of instruction	English

Modul **PAFMO002** Structure of Matter	
Module code	PAFMO002
Module title (German)	Structure of Matter
Module title (English)	Structure of Matter
Person responsible for the module	Prof. Dr. A. Tünnermann, Dr. O. Stenzel
Prerequisites for admission to the module	None
Type of module (compulsory module, required elective module, elective module)	Compulsory Module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 4 h per week Exercise: 2 h per week
ECTS credits	8 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	240 h 90 h 150 h
Content	• Classical interaction of light with matter • Basic knowledge on quantum mechanics • Einstein coefficients and Plancks formula • Selection rules • Hydrogen atom and helium atom • Introduction to molecular spectroscopy • Dielectric function and linear optical constants • Kramers-Kronig-Relations • Linear optical properties of crystalline and amorphous solids • Basic nonlinear optical effects
Intended learning outcomes	The course is an introduction to the principles of the optical response of materials.
Requirements for awarding credit points (type of examination)	Written examination (100%)
Recommended reading	• Demtröder, ”Experimental physics II” • Demtröder, ”Experimental physics III – atoms, molecules and solids” • R. Feynman, ”Feynman lectures on physics III quantum mechanics” • Jackson, ”Classical Electrodynamics • E. Hecht, ”Optics”
Language of instruction	English

Modul **PAFMO004** Laser Physics	
Module code	PAFMO004
Module title (German)	Laser Physics
Module title (English)	Laser Physics
Person responsible for the module	Prof. Dr. J. Limpert, Prof. Dr. S. Nolte
Prerequisites for admission to the module	None
Type of module (compulsory module, required elective module, elective module)	Required elective Module M.Sc. Physics focus „Optics” Compulsory Module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 4 h per week Exercise: 2 h per week
ECTS credits	8 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	240 h 90 h 150 h
Content	• Introduction to laser physics (stimulated emission, atomic rate equations, laser pumping and population inversion); • Optical beams and laser resonators; • Laser dynamics; • Q-switching; • Mode locking; • Wavelength tuning and single frequency operation; • Laser systems; • Selected industrial and scientific applications.
Intended learning outcomes	This course provides an introduction to the basic ideas of laser physics. The first part presents the fundamental equations and concepts of laser theory, while the second part is devoted to a detailed discussion of selected laser applications. The students are introduced to the different types of lasers including classical gas or ruby lasers as well as modern high-power diode pumped solid-state concepts and their applications.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%)

Recommended reading	• Siegman, Lasers; • W. Koechner, Solid-State Laser Engineering; • W. Demtröder, Laser Spectroscopy; • D. Bäuerle, Laser Processing and Chemistry; • H.-G. Rubahn, Laser Applications in Surface Science and Technology.
Language of instruction	English

Modul **PAFMO005** Optical Metrology and Sensing	
Module code	PAFMO005
Module title (German)	Optical Metrology and Sensing
Module title (English)	Optical Metrology and Sensing
Person responsible for the module	Prof. Dr. Herbert Gross
Prerequisites for admission to the module	None
Type of module (compulsory module, required elective module, elective module)	Compulsory Module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Basic principles • Wave optical fundamentals • Sensors • Fringe projection, triangulation • Interferometry and wave front sensing • Holography • Speckle methods and OCT • Phase retrieval • Metrology of aspheres and freeform surfaces • Confocal methods
Intended learning outcomes	This course covers the main principles of optical measurements and surface metrology.
Requirements for awarding credit points (type of examination)	Written examination (100%)
Language of instruction	English

Modul **PAFMO006** Introduction to Optical Modeling	
Module code	PAFMO006
Module title (German)	Introduction to Optical Modeling
Module title (English)	Introduction to Optical Modeling
Person responsible for the module	Prof. Dr. F. Wyrowski, apl. Prof. Dr. U. W. Zeitner
Prerequisites for admission to the module	None
Type of module (compulsory module, required elective module, elective module)	Required elective Module M.Sc. Physics focus „Optics” Compulsory Module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Concepts of ray tracing; • Modeling and design of lens systems; • Image formation; • Physical properties of lenses and lens materials in optical design; • Image aberrations and methods to avoid them; • Vectorial harmonic fields; • Plane waves; • Fourier transformation and spectrum of plane waves representation; • Concepts of field tracing; • Propagation techniques through homogeneous and isotropic media; • Numerical properties of propagation techniques.
Intended learning outcomes	The course aims to show how linear optics is applied for modeling and design of optical elements and systems. In the first part of the lecture we focus on ray-tracing techniques and its application through image formation. Then we combine the concepts with physical optics and obtain field tracing. It enables the propagation of vectorial harmonic fields through optical systems. In practical exercises the students will get an introduction to the use of commercial optics modeling and design software.
Requirements for awarding credit points (type of examination)	Written examination (100%)

Additional information on the module	
Recommended reading	• H. Gross, Handbook of Optical Systems Vol.1: Fundamentals of Technical Optics, Wiley-VCH; • L. Mandel and E. Wolf, Optical Coherence and Quantum Optics; • L. Novotny and B. Hecht, Principles of Nano-Optics.
Language of instruction	English

Modul **PAFMO007** Experimental Optics	
Module code	PAFMO007
Module title (German)	Experimental Optics
Module title (English)	Experimental Optics
Person responsible for the module	Prof. Dr. Stefan Nolte
Prerequisites for admission to the module	None
Type of module (compulsory module, required elective module, elective module)	Compulsory Module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Practical course
ECTS credits	6 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	180 h - h - h
Content	Practical training in optics. Topics cover a broad range, including refraction, optical lenses, interferometry, laser fundamentals, spectroscopy, optical tweezers, adaptive optics, etc.
Intended learning outcomes	• Introduction to experimental techniques in optics. • Planning and preparation of a scientific measuring task. • Carrying out scientific labwork in optics together with a research team. • Preparation of a scientific report.
Requirements for awarding credit points (type of examination)	Lab Work mark (100%) Consists of acceptance tests and written reports
Recommended reading	prepared electronic material describing the different labs which can be downloaded from www.asp.uni-jena.de/optics_labs
Language of instruction	English

Modul **PAFMO008** Internship	
Module code	PAFMO008
Module title (German)	Internship
Module title (English)	Internship
Person responsible for the module	Prof. Dr. Stefan Nolte
Prerequisites for admission to the module	Completion of the practical Module Experimental Optics
Recommended or expected prior knowledge	Practical Module Experimental Optics
Type of module (compulsory module, required elective module, elective module)	Compulsory Module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Practical course 300 h depending on the topic this total workload should be distributed approximately as: • 50 h introduction to the research topic (study of relevant literature, …) • 190 h research work (in the lab for experimental topics and at computer etc. for theoretical topics) • 50 h preparation of the final report • 10 h preparation and carrying out presentation of the results
ECTS credits	10 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	300 h - h - h
Content	Internship in industry or a research laboratory
Intended learning outcomes	• Carrying out scientific labwork in optics together with a research team. • Preparation of a written scientific report. • Presentation and defense of the results in an oral presentation.
Requirements for awarding credit points (type of examination)	Lab Work mark (100%) Consists of a written report (approximately 15-20 pages) and a final presentation (10-20 minutes) with subsequent discussion The final grade will be determined based on the research performance, the final report, and the presentation.
Recommended reading	specifically defined by the instructor of the internship
Language of instruction	English

Modul **PAFMO009** Research Lab

Module code	PAFMO009
Module title (German)	Research Lab
Module title (English)	Research Lab
Person responsible for the module	Prof. Dr. Thomas Pertsch
Prerequisites for admission to the module	Completion of the 2 practical Modules Experimental Optics and Internship
Type of module (compulsory module, required elective module, elective module)	Compulsory Module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Practical course total workload: 540 h depending on the topic this total workload should be distributed approximately as: • 150 h introduction to the research topic (study of relevant literature, …) • 270 h research work (in the lab for experimental topics and at computer etc. for theoretical topics) • 100 h preparation of the final report • 20 h preparation and carrying out presentation of the resultsh
ECTS credits	18 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	540 h - h - h
Content	Internship in a research laboratory
Intended learning outcomes	• Carrying out scientific labwork in optics together with a research team • Preparation of a scientific report • Presentation of the results in a written report
Requirements for awarding credit points (type of examination)	Lab Work mark (100%) Consists of a written report (approximately 20-30 pages) and a final presentation (15-25 minutes) with subsequent discussion The final grade will be determined based on the research performance, the final report, and the presentation.
Recommended reading	specifically defined by the instructor of the research team
Language of instruction	English

Modul **PAFMO100** Accelerator-based Modern Physics	
Module code	PAFMO100
Module title (German)	Beschleunigerbasierte moderne Physik
Module title (English)	Accelerator-based Modern Physics
Person responsible for the module	Prof. Dr. Th. Stöhlker
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Grundlagen der Atomphysik, Grundlagen der Elektrodynamik
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” and ”Solid State Physics/Material Science” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every semester
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week, Exercise: 1 h per week or seminar: 2 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	Basic concepts of particle accelerators, application of accelerators in basic science and medicine, landmark experiments
Intended learning outcomes	Gaining an overview of the various applications of particle accelerators, in particular for basic science, ability to solve exercise and to prepare a presentation
Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester or seminar talk
Requirements for awarding credit points (type of examination)	Oral examination (100%)
Recommended reading	• J. Eichler, • Lectures on Ion-Atom Collisions (Elsevier Science); • W. R. Leo, Techniques for Nuclear and Particle Physics Experiments (Springer)
Language of instruction	English (German on request)

Modul **PAFMO101** Active Photonic Devices	
Module code	PAFMO101
Module title (German)	Active Photonic Devices
Module title (English)	Active Photonic Devices
Person responsible for the module	Prof. Dr. M. Schmidt
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Basic knowledge in electrodynamics
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 40 h 80 h
Content	• Introduction; • Electro-optical modulation; • Acousto-optical devices; • Magneto-optics and optical isolation; • Integrated lasers; • Non-Linear devices for light generation;
Intended learning outcomes	The aim of this course is to give a comprehensive overview about active photonic devices such as switches or modulators. The course starts by a crisp introduction to the most important parameters and physical principles. The Lecture will then focus onto real-world devices including the areas of electro-optics, waveguides, acousto-optics, magneto-optics and non-linear optics. During this Lecture we will discuss the fundamental principles as well as devices currently employed in photonics. This Lecture will provide the students a base for their Master's thesis.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.

Recommended reading	• J. D. Jackson: Electrodynamics; • Yariv: Optical Electronics in Modern Communications; • Born/Wolf: Principles of Optics.
Language of instruction	English

Modul **PAFMO102** Analytical Instrumentations	
Module code	PAFMO102
Module title (German)	Analytical Instrumentations
Module title (English)	Analytical Instrumentations
Person responsible for the module	Dr. Adriana Szeghalmi, Prof. Dr. Andreas Tünnermann
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Atomic and molecular structure • Basics of atomic spectroscopy techniques • Molecular spectroscopy: absorption, emission, vibrational and spectroscopy and microspectroscopy, basics of magnetic resonance spectroscopy • Hardware of spectrometers/ microscopes: light sources, detectors, optics, material point of view • Current applications and relevance in material and life sciences
Intended learning outcomes	In this course, the student will learn about analytical methods to investigate structure and composition of matter. Basic principles of atomic and molecular structure will be refreshed towards better understanding experimental analysis techniques such as spectrophotometry, ellipsometry, fluorescence, infrared, Raman, etc. spectroscopy or microscopy. The course will focus on technological aspects of the experimental setup in analytical instrumentations. Modern applications of analytical instrumentations in material and life sciences will be discussed. After successful completion, the student will know their capabilities and limitations.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.

Recommended reading	• Atkins: Physical Chemistry (partial) • Lakowicz: Principles of fluorescence spectroscopy (partial) • Selected research publications and technical notes
Language of instruction	English

Modul **PAFMO103** Applied Laser Technology I	
Module code	PAFMO103
Module title (German)	Applied Laser Technology I
Module title (English)	Applied Laser Technology I
Person responsible for the module	Prof. Dr. C. Eggeling, Prof. Dr. R. Heintzmann and Prof. Dr. H. Stafast
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Overview over laser beam applications as a contactless and remote probe (macroscopic and microscopic, cw and ultrafast, dealing with spectroscopy, metrology, sensing, and multi-dimensional microscopy) • Fundamental concepts of related physical and physico-chemical effects • Absorption and emission of light (selection rules) • Ultrafast coherent excitation and relaxation (linear and non-linear optical processes) • Light reflection and elastic/inelastic scattering
Intended learning outcomes	• The course covers the fundamentals and concepts of the selected laser applications. • Learning to develop own solutions for challenges in laser applications
Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester and/or seminar talk on topic of own choice
Requirements for awarding credit points (type of examination)	Oral examination (100%)
Recommended reading	• Laser Spectroscopy, W. Demtröder, Springer • Molekülphysik und Quantenchemie, H. Haken u H. C. Wolf, Springer • Lasers in Chemistry, M. Lackner edit., Wiley-VCH 2008

Language of instruction	English

Modul **PAFMO104** Applied Laser Technology II	
Module code	PAFMO104
Module title (German)	Applied Laser Technology II
Module title (English)	Applied Laser Technology II
Person responsible for the module	Prof. Dr. R. Heintzmann, Prof. Dr. H. Stafast
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 2 h (bi-weekly)
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Applied Laser Technology using the laser as a tool • microscopic and macroscopic light-materials-interactions, • material preparation and modification (with the exception of classical laser materials´ processing)
Intended learning outcomes	In various selected topics out of the broad field of laser applications, the students should acquire knowledge of laser-material interactions (e.g. atom cooling and optical tweezer), laser induced processes in gases, liquids, and matrices (incl. laser isotope separation), materials´ preparation and structuring by ablation, deposition and/or modification.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Recommended reading	R. Paschotta, Encyclopedia of Laser Physics and Technology, Wiley-VCH
Language of instruction	English

Modul **PAFMO106** Atomic Physics at High Field Strengths	
Module code	PAFMO106
Module title (German)	Atomic Physics at High Field Strengths
Module title (English)	Atomic Physics at High Field Strengths
Person responsible for the module	Prof. Dr. Th. Stöhlker
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Basic knowledge in atomic physics and electrodynamics
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics", "Solid State Physics/Material Science" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every semester
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Strong field effects on the atomic structure • Relativistic and QED effects on the structure of heavy ions • X-ray spectroscopy of high-Z ions • Application in x-ray astronomy • Penetration of charged particles through matter • Particle dynamics in of atoms and ions in strong laser fields • Relativistic ion-atom and ion-electron collisions • Fundamental interaction processes • Scattering, absorption and energy loss • Detection methods • Particle creation
Intended learning outcomes	The Module provides insight into the basic techniques and concepts in physics related to extreme electromagnetic fields. Their relevance to nowadays applications will be discussed in addition. The Module also introduces the basic interaction processes of high-energy photon and particle beams with matter, including recent developments of high intensity radiation sources, such as free electron lasers and modern particle accelerators. Experimental methods and the related theoretical description will be reviewed in great detail.

Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester.
Requirements for awarding credit points (type of examination)	Oral examination (100%)
Recommended reading	• J. Eichler, Lectures on Ion-Atom Collisions (Elsevier Science); • W. R. Leo, Techniques for Nuclear and Particle Physics Experiments (Springer)
Language of instruction	English (German on request)

Modul **PAFMO107** Attosecond Laser Physics	
Module code	PAFMO107
Module title (German)	Attosecond Laser Physics
Module title (English)	Attosecond Laser Physics
Person responsible for the module	Jun.-Prof. Dr. A. Pfeiffer
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Module Strong-Field Laser Physics or equivalent
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Coherent electron dynamics in atoms and molecules; • Strong field effects and ionization; • High harmonic generation and phase matching; • Techniques for attosecond pulse generation; • Transient absorption; • Attosecond quantum optics with few-level quantum models.
Intended learning outcomes	The course gives an introduction into the young research field of attosecond physics. Electron dynamics in atoms and molecules on the attosecond time scale (which is the natural timescale for bound electrons) will be discussed, along with modern techniques for attosecond pulse generation and characterization.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Recommended reading	Zenghu Chang, Fundamentals of Attosecond Optics.
Language of instruction	English

Modul **PAFMO120** Biomedical Imaging - Ionizing Radiation	
Module code	PAFMO120
Module title (German)	Biomedical Imaging - Ionizing Radiation
Module title (English)	Biomedical Imaging - Ionizing Radiation
Person responsible for the module	Prof. Dr. J. R. Reichenbach, Prof. Dr. E. Förster
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Introduction to biomedical and medical imaging systems; • Physical principles behind the design of selected imaging systems; • Technological aspects of each modality; • Spatial and temporal resolution; • Importance of each modality concerning physical, biological and clinical applications.
Intended learning outcomes	The course introduces the physical principles, properties and technical concepts of imaging systems as they are applied today in medicine and physics. The focus is laid on the use and application of ionizing radiation, which has always been an important aspect of the application of physics to medicine. Applications and current developments will be presented. After having actively participated the students should demonstrate a critical understanding of the theoretical basis and technologies of these imaging systems and have acquired an appreciation of instrumentation and practical issues with different imaging systems. The course is independent of the course Biomedical Imaging – Non-Ionizing Radiation offered in the 2nd semester and does not require previous participation of that course.
Requirements for awarding credit points (type of examination)	Oral examination (100%)

Recommended reading	• Oppelt, Imaging Systems for Medical Diagnostics: Fundamentals, Technical Solutions and Applications for Systems Applying Ionizing Radiation, Nuclear Magnetic Resonance and Ultrasound, Publicis, 2nd edition, 2006; • P. Suetens, Fundamentals of Medical Imaging, Cambridge University Press; 2nd edition, 2009; • W.R. Hendee, E.R. Ritenour, Medical Imaging Physics, Wiley-Liss, 4th edition, 2002.
Language of instruction	English

Modul **PAFMO121** Biomedical Imaging - Non Ionizing Radiation	
Module code	PAFMO121
Module title (German)	Biomedical Imaging - Non Ionizing Radiation
Module title (English)	Biomedical Imaging - Non Ionizing Radiation
Person responsible for the module	Prof. Dr. J. R. Reichenbach, Prof. Dr. E. Förster
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 30 h 90 h
Content	• Introduction to imaging systems; • Physical principles behind the design of selected biomedical imaging systems, including magnetic resonance imaging, ultrasound imaging; • Technological aspects of each modality; • Importance of each modality concerning physical, biological and clinical applications.
Intended learning outcomes	The course introduces physical principles, properties and technical concepts of imaging systems as they are applied today in medicine and physics. The focus is laid on the use and application of non-ionizing radiation, as utilized, e.g., with magnetic resonance imaging or ultrasound imaging. Applications and current developments will be presented. After active participation the students should demonstrate a critical understanding of the theoretical basis and technologies of these imaging systems and have acquired an appreciation of instrumentation and practical issues with different imaging systems. The course is independent of the course Biomedical Imaging – Ionizing Radiation offered in the 3rd semester.
Requirements for awarding credit points (type of examination)	Oral examination (100%)

Recommended reading	• Oppelt. Imaging Systems for Medical Diagnostics: Fundamentals, Technical Solutions and Applications for Systems Applying Ionizing Radiation, Nuclear Magnetic Resonance and Ultrasound, Publicis, 2nd edition, 2006; • J.T. Bushberg et al., The Essential Physics of Medical Imaging, Lippincott Raven, 3rd edition, 2011; • R.W. Brown, Y.-C. N. Cheng, E. M. Haacke, M.R. Thompson, R. Venkatesan, Magnetic Resonance Imaging: Physical Principles and Sequence Design, Wiley, 2nd edition, 2014.
Language of instruction	English

Modul **PAFMO122** Biophotonics	
Module code	PAFMO122
Module title (German)	Biophotonics
Module title (English)	Biophotonics
Person responsible for the module	Prof. Dr. Rainer Heintzmann, Prof. Dr. Stefan H. Heinemann
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 60 h 60 h
Content	The Module provides a deep introduction into the multitude of possible linear and non-linear light biological matter interaction phenomena and thus in modern techniques and applications of frequency-, spatially-, and time-resolved bio-spectroscopy. The course presents a comprehensive overview over modern spectroscopic and optical imaging techniques inclusive specific theoretical methodologies to analyze the experimental spectroscopic data to resolve problems in life sciences. The biological part introduces to molecular and cellular properties of living organisms, explains some major components of physiological function and diseases and sets the stage for biophotonics applications by highlighting some key methods necessary to prepare biological material for photonics experiments and by showing several examples of how biophotonics can help to shed light on biologically and clinically relevant processes. The Module spans aspects of the scientific disciplines chemistry, physics, biology and medicine.The Exercises will be partly calculating examples and partly in the form a seminar talks of the students presenting current research publications..
Intended learning outcomes	The aim of this course is to present modern methods in spectroscopy, microscopy and imaging dedicated to biological samples. After the course the students will be able to choose and to apply appropriate spectroscopic methods and imaging technologies to resolve special biophotonic problems.

Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Recommended reading	• Paras N. Prasad, Introduction to Biophotonics • Textbooks on laser spectroscopy, e.g. Demtröder; on quantum mechanics, e.g. Atkins and on optics, e.g. Zinth/Zinth • Jerome Mertz: Introduction to Optical Microscopy, Roberts & Company Publishers, 2010 • Selected chapters of Handbook of Biophotonics (Ed. J. Popp) WILEY
Language of instruction	English

Modul **PAFMO130** Computational Photonics	
Module code	PAFMO130
Module title (German)	Computational Photonics
Module title (English)	Computational Photonics
Person responsible for the module	Prof. Dr. T. Pertsch
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Fundamental knowledge on modern optics and condensed matter physics as well as basic knowledge of a computer programming language and computational physics
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Introduction to the problem – Maxwell's equations and the wave equation; • Free space propagation techniques; • Beam propagation methods applied to problems in integrated optics; • Mode expansion techniques applied to stratified media; • Mode expansion techniques applied to spherical and cylindrical objects; • Multiple multipole technique; • Boundary integral method; • Finite-Difference Time-Domain method; • Finite Element Method; • Computation of the dispersion relation (band structure) of periodic media; • Mode expansion techniques applied to gratings; • Other grating techniques; • Contemporary problems in computational photonics.

Intended learning outcomes	The course aims at an introduction to various techniques used for computer based optical simulation. Therefore, the student should learn how to solve Maxwell's equations in homogenous and inhomogeneous media rigorously as well as on different levels of approximation. The course concentrates predominantly on teaching numerical techniques that are useful in the field of micro- and nanooptics.
Requirements for awarding credit points (type of examination)	Written examination (100%)
Recommended reading	• Taflove and S.C. Hagness, Computational Electrodynamics; • list of selected journal publications given during the lecture.
Language of instruction	English

Modul **PAFMO131** Fundamental Atomic and Nuclear Processes in Highly Ionized Matter	
Module code	PAFMO131
Module title (German)	Fundamental Atomic and Nuclear Processes in Highly Ionized Matter
Module title (English)	Fundamental Atomic and Nuclear Processes in Highly Ionized Matter
Person responsible for the module	Prof. Dr. Th. Stöhlker
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Basic knowledge in atomic an nuclear physics
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” , ”Solid State Physics/Material Science” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every semester
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week, Excercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	Lecture 1: "X-ray spectroscopy of hot plasmas" • basic properties of atomic systems (level structure, transition rates, etc.) • atomic charge-exchange processes in plasmas, charge state distributions • creation of plasmas: facilities for stored and trapped ions • x-ray detectors and techniques for spectroscopy and polarimetry • x-ray diagnosis of plasmas in the laboratory and nature Lecture 2: "Nuclear matter and the formation of elements" • Properties of nuclear matter • Stability of the atomic nucleus • Nuclear models and masses of atomic nuclei • Nuclear processes related to the creation of the elements • Nuclear radiation and radiation detectors • Experimental techniques
Intended learning outcomes	Gaining an overview of experiments addressing astrophysical topics, in particular concerning ionized matter

Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester.
Requirements for awarding credit points (type of examination)	Oral examination (100%)
Additional information on the module	The above mentioned lectures are offered alternately.
Language of instruction	English (German on request)

Modul **PAFMO132** Design and Correction of Optical Systems	
Module code	PAFMO132
Module title (German)	Design and Correction of Optical Systems
Module title (English)	Design and Correction of Optical Systems
Person responsible for the module	Prof. Dr. H. Gross
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Basic knowledge in geometrical and physical optics.
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Basic technical optics; • Paraxial optics; • Imaging systems; • Aberrations; • Performance evaluation of optical systems; • Correction of optical systems; • Optical system classification; • Special system considerations.
Intended learning outcomes	This course covers the fundamental principles of classical optical system design, the performance assessment and the correction of aberrations. In combination of geometrical optics and physical theory the students will learn the basics to understand optical systems, which can be important for experimental work.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMO140** Diffractive Optics	
Module code	PAFMO140
Module title (German)	Diffractive Optics
Module title (English)	Diffractive Optics
Person responsible for the module	Prof. Dr. Frank Wyrowski
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Modeling diffraction of light fields • Diffraction vs. scattering • Diffraction at gratings • Diffractive and Fresnel lens modeling and design • Modeling and design of diffractive beam splitters and diffusers • Modeling of microlens arrays • Modeling and design of cell-oriented diffractive elements • Application and modeling of Spatial Light Moduleators (SLM)
Intended learning outcomes	Diffractive optics is widely recognized as an important enabling technology in modern optics. The control of light fields by microstructured media, which is the essence of diffractive optics, opens a large number of avenues in optical research and engineering. In this Lecture, the basic modeling and design principles of diffractive optics are considered. Various scenarios from different applications are investigated.
Requirements for awarding credit points (type of examination)	written examination (100%)
Recommended reading	• E. Hecht and A. Zajac, Optics • M. Born and E. Wolf, Principles of Optics • J. Turunen and F. Wyrowski, Diffractive Optics for industrial and commercial applications, Akademie Verlag, 1997

Language of instruction	English

Modul **PAFMO150** Renewable Energies	
Module code	PAFMO150
Module title (German)	Erneuerbare Energien
Module title (English)	Renewable Energies
Person responsible for the module	Prof. Dr. G. G. Paulus
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics Required elective module LA Physik
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Basics of energy supply in Germany; • Potential of renewable energies; • Principles of the energy balance of planets • Thermodynamics of the atmosphere; • Physics of wind energy systems; • Elements of solar power generation.
Intended learning outcomes	Teaching of knowledge on the fundamentals of renewable energies. Development of skills for the independent evaluation of different types of renewable energies.
Prerequisites for admission to the module examination	Details will be defined at the beginning of the semester.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Recommended reading	• Gasch, Twele: Windkraftanlagen; • De Vos: Thermodynamics of Solar Energy Conversion.
Language of instruction	English or German depending on audience

Modul **PAFMO151** Experimental Nonlinear Optics	
Module code	PAFMO151
Module title (German)	Experimental Nonlinear Optics
Module title (English)	Experimental Nonlinear Optics
Person responsible for the module	Prof. Dr. G. G. Paulus
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Propagation of light in crystals; • Properties of the non-linear susceptibility tensor; • Description of light propagation in non-linear media; • Parametric effects; • Second harmonic generation; • Phase-matching; • Propagation of ultrashort pulses; • High-harmonic generation; • Solitons
Intended learning outcomes	This course gives an introduction to optics in non-linear media and discusses the main non-linear effects.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Recommended reading	• Boyd, Non-Linear optics; • Zernike/Midwinter, Applied non-linear optics; • Sauter, Non-Linear optics.
Language of instruction	English

Modul **PAFMO160** Fiber Optics	
Module code	PAFMO160
Module title (German)	Fiber Optics
Module title (English)	Fiber Optics
Person responsible for the module	Prof. Dr. M. Schmidt
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Basic knowledge on modern optics and condensed matter physics.
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Properties of optical fibers; • Light propagation in optical fibers; • Technology and characterization techniques; • Special fiber types (photonic crystal fibers, hollow fibers, polarization maintaining fibers; • Fiber devices (e.g. fiber amplifiers and lasers); • Applications
Intended learning outcomes	This course introduces properties of different types of optical fiber waveguides. Applications of optical fibers and optical sensing will be discussed.
Prerequisites for admission to the module examination	none
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Recommended reading	• Snyder/Love, Optical Waveguide Theory; • Okamoto, Fundamentals of Optical Waveguides.

Language of instruction	English

Modul **PAFMO165** Fundamentals of Laser Physics	
Module code	PAFMO165
Module title (German)	Grundlagen der Laserphysik
Module title (English)	Fundamentals of Laser Physics
Person responsible for the module	Prof. Dr. J. Limpert, Dr. Jan Rothhardt
Prerequisites for admission to the module	None
Recommended or expected prior knowledge	Modules Quantum Theory and Atoms and Molecules or equivalent
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics"
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 2 h per week
ECTS credits	6 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	180 h 60 h 120 h
Content	• laser principle and essential laser types; • Pumping concepts and optical amplification; • Stable and unstable resonators; • single frequency lasers; • ultrafast lasers; • essential laser types and their characteristics.
Intended learning outcomes	• Fundamentals of absorption and emission; • inversion / optical amplification; • concepts for generating coherent light; • Laser principle; • Basic principles of non-linear optics.
Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.

Recommended reading	• Optik, Licht und Laser, D. Meschede; • Lasers, T. Siegman; • Laser, F. K. Kneubühl; • Laser – Grundlagen, Systeme, Anwendungen, J. und H.-J. Eichler, Springer; • Laser Spectroscopy, W. Demtröder.
Language of instruction	German

Modul **PAFMO170** High-Intensity/Relativistic Optics	
Module code	PAFMO170
Module title (German)	High-Intensity/Relativistic Optics
Module title (English)	High-Intensity/Relativistic Optics
Person responsible for the module	Prof. Dr. M. Kaluza
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• High-intensity laser technology; • Laser plasma physics; • Laser accelerated particles and applications.
Intended learning outcomes	The interaction of high intensity light fields with matter is the subject of this course. The students should learn the basic ideas of high intensity laser technology and its applications.
Prerequisites for admission to the module examination	none
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Recommended reading	• W. L. Kruer, The Physics of Laser Plasma Interactions, Westview press (2003), Boulder Colorado; • P. Gibbon, Short Pulse Laser Interactions with Matter, Imperial College Press (2005), London; • F. F. Chen, Introduction to Plasma Physics and Controlled Fusion, Vol. 1: Plasma Physics, Springer (1984).
Language of instruction	English

Modul **PAFMO171** History of Optics	
Module code	PAFMO171
Module title (German)	Geschichte der Optik
Module title (English)	History of Optics
Person responsible for the module	Prof. Dr. C. Spielman, Dr. C. Forstner
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Seminar: 2 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 30 h 90 h
Content	The seminar covers the history of optics from the antiquity to the 20th century: Starting with Greek heories of vision and ending with quantum optics. A strong focus will be given on the development of concepts and experiments that influenced todays thinking about light and optics, such as wave particle dualism or the Abbe diffraction limit. An excursion the Jena's Optical Museum is part of the seminar.
Intended learning outcomes	In close collaboration with the supervisor, the student will work on an independent project. The students will develop the ability to evaluate critically the arguments and analytical methods of historians. They will learn developing their own interpretations based on critical assessments of primary source evidence and independent research.
Requirements for awarding credit points (type of examination)	Scientific Talk (100%)
Recommended reading	• David C. Lindberg, Theories of Vision from al Kindi to Kepler. Chicago: University of Chicago Press, 1976. • Olivier Darrigol, A History of Optics: From Greek Antiquity to the Nineteenth Century. Oxford: Oxford University Press, 2012. • Helge Kragh, Quantum Generations: A History of Physics of the Twentieth Century. Princeton: Princeton University Press, 1999.
Language of instruction	German, English

Modul **PAFMO180** Image Processing	
Module code	PAFMO180
Module title (German)	Image Processing
Module title (English)	Image Processing
Person responsible for the module	Prof. Dr. Joachim Denzler
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Digital image fundamentals (Image Sensing and Acquisition, Image Sampling and Quantization) • Image Enhancement in the Spatial Domain (Basic Gray Level Transformations, Histogram Processing, Spatial Filtering) • Image Enhancement in the Frequency Domain (Introduction to the Fourier-Transform and the Frequency Domain, Frequency Domain Filtering, Homomorphic Filtering) • Image Restoration (Noise Models, Inverse Filtering, Geometric Distortion) • Color Image Processing Image Segmentation (Detection of Discontinuities, Edge Linking and Boundary Detection, Thresholding, Region-Based Segmentation) • Representation and Description Applications
Intended learning outcomes	The course covers the fundamentals of digital image processing. Based on this the students should be able to identify standard problems in image processing to develop individual solutions for given problems and to implement image processing algorithms for use in the experimental fields of modern optics.
Prerequisites for admission to the module examination	

Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Recommended reading	Gonzalez, Woods, Digital Image Processing, Prentice Hall, 2001
Language of instruction	English

Modul **PAFMO181** Image Processing in Microscopy	
Module code	PAFMO181
Module title (German)	Image Processing in Microscopy
Module title (English)	Image Processing in Microscopy
Person responsible for the module	Prof. Dr. Rainer Heintzmann
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	All the image processing and simulations will be practiced in exercises using MatLab and the free image processing toolbox DIPImage (www.diplib.org). The student needs to be familiar with MatLab at a basic level and with basic concepts of image processing such as filtering and thresholding. The Image Processing lecture by Prof. Denzler in the second term forms a good basis for this course.
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	We will show different methodologies to extract specific information such as for example the average speed of diffusing particles or the locations and areas of cells from the multidimensional image data. Also fitting quantitative models to extracted data will be treated.Simulation of far-field intensity distribution by using simple Fourier-space based approaches is treated with and without considering the vectorial nature of the oscillating electro-magnetic field.

Intended learning outcomes	Current microscopy often acquires a large amount of image data from which the biological or clinical researcher often needs to answer very specific questions.A major topic is the reconstruction of the sample from the acquired, often complex, microscopy data. To solve such inverse problems, a good model of the data acquisition process is required, ranging from assumptions about the sample (e.g. a positive concentration of molecules per voxel), assumptions about the imaging process (e.g. the existence of an incoherent spatially invariant point spread function) to modeling the noise characteristics of the detection process (e.g. read noise and photon noise).
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Recommended reading	
Language of instruction	English, German if requested

Modul **PAFMO182** Imaging and Aberration Theory	
Module code	PAFMO182
Module title (German)	Imaging and Aberration Theory
Module title (English)	Imaging and Aberration Theory
Person responsible for the module	Prof. Dr. H. Gross
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Basic knowledge in geometrical and physical optics.
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Paraxial imaging; • Basics of optical systems; • Eikonal theory; • Geometrical aberrations, representations, expansion; • Detailed discussion of primary aberrations; • Sine condition, isoplanatism, afocal cases; • Wave aberrations and Zernike representation; • Miscellaneous aspects of aberration theory.
Intended learning outcomes	This course covers the fundamental principles of classical optical imaging and aberration theory of optical systems.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMO183** Introduction to Nanooptics	
Module code	PAFMO183
Module title (German)	Introduction to Nanooptics
Module title (English)	Introduction to Nanooptics
Person responsible for the module	Jun.-Prof. Dr. I. Staude, Prof. Dr. T. Pertsch
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Fundamental knowledge on modern optics and condensed matter physics
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Surface-plasmon-polaritons; • Plasmonics; • Photonic crystals; • Fabrication and optical characterization of nanostructures; • Photonic nanomaterials / metamaterials / metasurfaces; • Optical nanoemitters; • Optical nanoantennas.
Intended learning outcomes	The course provides an introduction to the broad research field of nanooptics. The students will learn about different concepts which are applied to control the emission, propagation, and absorption of light at subwavelength spatial dimensions. Furthermore, they will learn how nanostructures can be used to optically interact selectively with nanoscale matter, a capability not achievable with standard diffraction limited microscopy. After successful completion of the course the students should be capable of understanding present problems of the research field and should be able to solve basic problems using advanced literature.
Prerequisites for admission to the module examination	none

Requirements for awarding credit points (type of examination)	Module mark (100%) Consists of a written examination and an oral presentation on a current research topic.
Additional information on the module	
Recommended reading	• L. Novotny and B. Hecht, Principles of Nano-Optics, Cambridge 2006; • P. Prasad, Nanophotonics, Wiley 2004; • J. D. Joannopoulos, S. G. Johnson, J. N. Winn, R. D. Meade, Photonic Crystals – Molding the Flow of Light, Princeton University Press (2008) • list of selected journal publications given during the lecture.
Language of instruction	English

Modul **PAFMO200** Laser Driven Radiation Sources	
Module code	PAFMO200
Module title (German)	Laser Driven Radiation Sources
Module title (English)	Laser Driven Radiation Sources
Person responsible for the module	Prof. Matt Zepf
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Basic knowledge in electrodynamics and plasma physics
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Laser Plasma Interactions • Principles of Plasma Accelerators • Ultrafast Photon Sources • Scattering of photons from particle beams
Intended learning outcomes	The course introduces the basic interaction processes of high-energy lasers with plasmas and particle beams with a particular emphasis on the extremely intense sources of proton, electron and photons with pulse durations in the femtosecond regime.
Requirements for awarding credit points (type of examination)	presentation and/or oral examination (100%)
Recommended reading	Gibbon, Short Pulse Laser Interactions with Matter
Language of instruction	English/German depending on participants

Modul **PAFMO201** Laser Engineering	
Module code	PAFMO201
Module title (German)	Laser Engineering
Module title (English)	Laser Engineering
Person responsible for the module	Prof. Dr. Malte Kaluza
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Prior knowledge in electrodynamics and laser physics is strongly recommended.
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 2 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• origin and dependencies of absorption and emission cross sections • Ytterbium based laser media • design of laser diode pump engines, • special topics in geometrical optics for amplifier design • basic calculations for layout of diode pumped high energy amplifiers • Ytterbium based laser materials and cryogenic cooling • limitations and special topics (laser induced damage threshold (LIDT), amplified spontaneous emission (ASE) …)
Intended learning outcomes	This is an application oriented course focusing on topics needed for development and design of diode pumped high energy class laser systems. Besides general topics the main part of this lecture is dedicated to ytterbium based laser systems. Besides basic knowledge like the spectral properties of laser materials and their significance for a laser system, further key topics like laser induced damage thresholds, laser diode pump engines, modeling of amplification and amplified spontaneous emission will be discussed.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.

Recommended reading	• Koechner, W. (2013). Solid-state laser engineering (Vol. 1). Springer. • Träger, F. (Ed.). (2012). Springer handbook of lasers and optics. Springer Science & Business Media. • Wood, R. M. (2003). Laser-induced damage of optical materials. CRC Press.
Language of instruction	English

Modul **PAFMO203** Lens Design I	
Module code	PAFMO203
Module title (German)	Lens Design I
Module title (English)	Lens Design I
Person responsible for the module	Prof. Dr. H. Gross
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Basic knowledge in geometrical and physical optics.
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Introduction and user interface; • Description and properties of optical systems; • Geometrical and wave optical aberrations; • Optimization; • Imaging simulation; • Introduction into illumination systems; • Correction of simple systems; • More advanced handling and correction methods.
Intended learning outcomes	This course gives an introduction in layout, performance analysis and optimization of optical systems with the software Zemax.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMO204** Lens Design II	
Module code	PAFMO204
Module title (German)	Lens Design II
Module title (English)	Lens Design II
Person responsible for the module	Prof. Dr. H. Gross
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Basic knowledge in aberration theory and optical design.
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics“ Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Paraxial imaging and basic properties of optical systems; • Initial systems and structural modifications; • Chromatical correction; • Aspheres and freeform surfaces; • Optimization strategy and constraints; • Special correction features and methods; • Tolerancing and adjustment.
Intended learning outcomes	This course covers the advanced principles of the development of optical systems.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMO205** Light Microscopy	
Module code	PAFMO205
Module title (German)	Light Microscopy
Module title (English)	Light Microscopy
Person responsible for the module	Prof. Dr. Rainer Heintzmann
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	Starting from geometrical optics the imaging system will be described and optical aberrations will be discussed. Moving on to wave optics monochromatic waves will be taken as the basis for the description of coherent imaging. Combined with scattering theory in the 1st Born approximation a fundamental understanding of the possibilities and limitations in imaging is gained. The concept of the amplitude transfer function and McCutchens 3-dimensional pupil function are introduced. On this basis various coherent imaging modes are discussed including holographic approaches and their limitations, and optical coherent tomography. The working principles of light-detectors are discussed and the requirements for appropriate sampling of images. Finally various modes of fluorescence microscopy and high-resolution microscopy will be covered. The exercises will be calculating examples, also involving hands-on computer based modeling using Matlab and other tools.
Intended learning outcomes	Understanding of the working principles of modern light microscopes and microscopic methods ranging from standard methods to modern superresolution techniques.

Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMO206** Light Source Modeling	
Module code	PAFMO206
Module title (German)	Light Source Modeling
Module title (English)	Light Source Modeling
Person responsible for the module	Prof. Dr. Frank Wyrowski
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Special cases of monochromatic fields • Gaussian beams and its propagation • Electromagnetic coherence theory; cross spectral density • Cross spectral density and polarization matrices • Stokes vectors and Mueller matrix • Mode decomposition of general source fields • Elementary mode decomposition • System modeling with partially coherent source fields • System modeling with ultrashort pulses • All techniques are demonstrated at hands-on examples
Intended learning outcomes	The application and usage of optical technologies benefit significantly from the ever growing variety of light sources with different characteristics and reasonable prices. LEDs, lasers and laser diodes have become indispensable in numerous applications and devices. Ultrashort pulses are on the way to industrial and medical applications. X-ray sources are of increasing importance. All those sources require a suitable approach in optical modeling and design. The students will get a comprehensive overview of different source modeling techniques of practical importance in optical modeling and design.
Requirements for awarding credit points (type of examination)	Written examination (100%)

Recommended reading	• E. Hecht and A. Zajac, Optics • M. Born and E. Wolf, Principles of Optics • L. Mandel and E. Wolf, Optical Coherence and Quantum Optics • B.E.A. Saleh and M.C. Teich, Fundamentals of Photonics
Language of instruction	English

Modul **PAFMO220** Micro/Nanotechnology	
Module code	PAFMO220
Module title (German)	Micro/Nanotechnology
Module title (English)	Micro/Nanotechnology
Person responsible for the module	Dr. habil. Uwe Zeitner
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• demands of micro- and nano-optics on fabrication technology • basic optical effects of micro- and nano-structures and their description • typical structure geometries in micro- and nano-optics • coating technologies • lithography (photo-, laser-, electron-beam) and its basic physical principles • sputtering and dry etching • special technologies (melting, reflow, …) • applications and examples
Intended learning outcomes	In this course the student will learn about the fundamental fabrication technologies which are used in microoptics and nanooptics. This includes an overview of the physical principles of the different lithography techniques, thin film coating and etching technologies. After successful completion of the course the students should have a good overview and understanding of the common technologies used for the fabrication of optical micro- and nano-structures. They know their capabilities and limitations.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.

Language of instruction	English

Modul **PAFMO221** Microscopy	
Module code	PAFMO221
Module title (German)	Microscopy
Module title (English)	Microscopy
Person responsible for the module	Prof. Dr. R. Heintzmann, Prof. Dr. C. Eggeling
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Optical microscopy • Circumventing the resolution limit • Electron microscopy • Atomic force microscopy
Intended learning outcomes	This Module provides an introduction into the fundamentals of modern light and electron microscopy.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMO222** Modern Methods of Spectroscopy	
Module code	PAFMO222
Module title (German)	Moderne Methoden der Spektroskopie
Module title (English)	Modern Methods of Spectroscopy
Person responsible for the module	Prof. Dr. C. Spielmann
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics"
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Fundamentals of light-matter interaction; • Experimental tools of spectroscopy; • laser spectroscopy; • Time-resolved spectroscopy; • Laser cooling; • THz and X-ray spectroscopy; • photoelectron spectroscopy; • Applications of laser spectroscopy in physics, chemistry, medicine.
Intended learning outcomes	• Understanding the methods of spectroscopy based on new developments in optics; • impart knowledge about the design of a spectroscopic experiment; • Ability to independently solve spectroscopic questions.
Prerequisites for admission to the module examination	Active participation in the discussions in the seminar.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	German, English

Modul **PAFMO230** Nano Engineering	
Module code	PAFMO230
Module title (German)	Nano Engineering
Module title (English)	Nano Engineering
Person responsible for the module	Dr. Stephanie Höppener, Prof. Dr. Ulrich S. Schubert
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Building with Molecules • Self-organization and self-assembled coatings • Chemically sensitive characterization methods • Nanomaterials for optical applications • Nanowires and nanoparticles • Nanomaterials in optoelectronics • Bottom-up synthesis strategies and nanolithography • Polymers and self-healing coatings • Molecular motors • Controlled polymerization techniques

Intended learning outcomes	A large diversity of nanomaterials can be efficiently produced by utilizing chemical synthesis strategies. The wide range of nanomaterials, i.e., nanoparticles, nanotubes, micelles, vesicles, nanostructured phase separated surface layers etc. opens on the one hand versatile possibilities to build functional systems, on the other hand also the large variety of techniques and processes to fabricate such systems is also difficult to overlook. Traditionally the communication in the interdisciplinary field of nanotechnology is difficult, as expertise from different research areas is combined. This course aims on the creation of a common basic level for communication and knowledge of researchers of different research fields and to highlight interdisciplinary approaches which lead to new fabrication strategies. The course includes basic chemical synthesis strategies, molecular self-assembly processes, chemical surface structuring, nanofabrication and surface chemistry to create a pool of knowledge to be able to use molecular building blocks in future research projects.
Prerequisites for admission to the module examination	Assignments
Requirements for awarding credit points (type of examination)	Oral examination (100%)
Recommended reading	• G. Cao, Nanostructures & Nanomaterials: Synthesis, Properties & Applications, Imperial College Press, 2004 • G.A. Ozin, A.C. Arsenault, L. Cademartiri, A Chemical Approach to Nanomaterials, Royal Soc. Of Chemistry, 2nd Ed., 2009 • L.F. Chi, Nanotechnology Vol. 8 Nanostructured Surfaces, Wiley-VCH, 2010
Language of instruction	English

Modul **PAFMO231** Nonlinear Dynamics in Optical Systems	
Module code	PAFMO231
Module title (German)	Nonlinear Dynamics in Optical Systems
Module title (English)	Nonlinear Dynamics in Optical Systems
Person responsible for the module	Prof. Dr. U. Peschel
Prerequisites for admission to the module	none
Recommended or expected prior knowledge	Basic knowledge in electrodynamics
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics" Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Non-Linear dynamics in optical fibers and waveguides • Solution of non-linear partial differential equations • Solitons and collapse in optical systems • Super continuum generation
Intended learning outcomes	Understanding the theoretical fundamentals of non-linear dynamics in optical systems
Requirements for awarding credit points (type of examination)	Examination mark (100%) The mark is composed by an Exercise mark (25%) and an oral examination (75%)
Recommended reading	• Agrawal, Govind P. Non-Linear optics • Moloney, Jerome V., Newell Alan C., Non-Linear Optics • Y.S.Kivshar and G.Agrawal, Optical Solitons: From Fibers to Photonic Crystals
Language of instruction	German or English on request

Modul **PAFMO242** Optics for Spectroscopists: Optical Waves in Solids	
Module code	PAFMO242
Module title (German)	Optics for Spectroscopists: Optical Waves in Solids
Module title (English)	Optics for Spectroscopists: Optical Waves in Solids
Person responsible for the module	Dr. habil. Thomas Mayerhöfer
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Reflection and Refraction at anisotropic interfaces (Yeh's formalism, Berreman formalism, special cases, Euler orientation representations, example spectra etc.) • Dispersion relations in isotropic and anisotropic crystals (Lorentz-model, coupled oscillator model, semi-empirical 4-Parameter model, inverse dielectric function modelling etc.) • Dispersion analysis of crystals and layered systems down to triclinic symmetry and, ultimately, without prior knowledge of orientation; consequences for randomly-oriented or partly-oriented systems.
Intended learning outcomes	The students will acquire an understanding how the optical properties of anisotropic materials are connected with the material properties and how they depend on frequency. The final goal is to be able to quantitatively understand and analyze spectral patterns of crystals and layers of arbitrary symmetry and orientation.
Requirements for awarding credit points (type of examination)	Oral examination (100%)
Recommended reading	• Optical Waves in Layered Media, Pochi Yeh,Wiley, 2005 • Absorption and Scattering of Light by Small Particles Craig F. Bohren, Donald R. Huffman, 1998 • The Infrared spectra of minerals, Victor Colin Farmer, Mineralogical Society, 1974

Language of instruction	English

Modul **PAFMO250** Particles in Strong Electromagnetic Fields	
Module code	PAFMO250
Module title (German)	Particles in Strong Electromagnetic Fields
Module title (English)	Particles in Strong Electromagnetic Fields
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO251** Physical Optics Design	
Module code	PAFMO251
Module title (German)	Physical Optics Design
Module title (English)	Physical Optics Design
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO252** Physical Optics Modeling	
Module code	PAFMO252
Module title (German)	Physical Optics Modeling
Module title (English)	Physical Optics Modeling
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO253** Physics of Free-Electron Laser	
Module code	PAFMO253
Module title (German)	Physics of Free-Electron Laser
Module title (English)	Physics of Free-Electron Laser
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO254** Physics of Ultrafast Optical Discharge and Filamentation	
Module code	PAFMO254
Module title (German)	Physics of Ultrafast Optical Discharge and Filamentation
Module title (English)	Physics of Ultrafast Optical Discharge and Filamentation
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO255** Plasma Physics	
Module code	PAFMO255
Module title (German)	Plasma Physics
Module title (English)	Plasma Physics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO260** Quantum Optics

Module code	PAFMO260
Module title (German)	Quantum Optics
Module title (English)	Quantum Optics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO265** Semiconductor Nanomaterials	
Module code	PAFMO265
Module title (German)	Semiconductor Nanomaterials
Module title (English)	Semiconductor Nanomaterials
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO266** Strong-Field Laser Physics	
Module code	PAFMO266
Module title (German)	Strong-Field Laser Physics
Module title (English)	Strong-Field Laser Physics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO270** Theory of Nonlinear Optics	
Module code	PAFMO270
Module title (German)	Theory of Nonlinear Optics
Module title (English)	Theory of Nonlinear Optics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO271** Thin Film Optics	
Module code	PAFMO271
Module title (German)	Thin Film Optics
Module title (English)	Thin Film Optics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO272** Terahertz Technology	
Module code	PAFMO272
Module title (German)	Terahertz Technology
Module title (English)	Terahertz Technology
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO280** Ultrafast Optics	
Module code	PAFMO280
Module title (German)	Ultrafast Optics
Module title (English)	Ultrafast Optics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in winter semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO290** XUV and X-Ray Optics

Module code	PAFMO290
Module title (German)	XUV and X-Ray Optics
Module title (English)	XUV and X-Ray Optics
Frequency of offer (how often is the module offered?)	Every second semester (beginning in summer semester)
Duration of module	1 semester
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h

Modul **PAFMO901** Topics of Current Research 1	
Module code	PAFMO901
Module title (German)	Topics of Current Research I
Module title (English)	Topics of Current Research 1
Person responsible for the module	N.N.
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	At irregular intervals
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Advanced topics of current research in optics and photonics
Intended learning outcomes	• Introduction into a field of current ressearch as a basis for further study and research in this field; • Independent solution of Exercise problems; • Ability to acquire further knowledge by independent literature studies.
Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMO902** Topics of Current Research 2	
Module code	PAFMO902
Module title (German)	Topics of Current Research II
Module title (English)	Topics of Current Research 2
Person responsible for the module	N.N.
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	At irregular intervals
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Advanced topics of current research in optics and photonics
Intended learning outcomes	• Introduction into a field of current ressearch as a basis for further study and research in this field; • Independent solution of exercise problems; • Ability to acquire further knowledge by independent literature studies.
Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMO903** Topics of Current Research 3	
Module code	PAFMO903
Module title (German)	Topics of Current Research III
Module title (English)	Topics of Current Research 3
Person responsible for the module	N.N.
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	At irregular intervals
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Advanced topics of current research in optics and photonics
Intended learning outcomes	• Introduction into a field of current ressearch as a basis for further study and research in this field; • Independent solution of Exercise problems; • Ability to acquire further knowledge by independent literature studies.
Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMO904** Topics of Current Research 4	
Module code	PAFMO904
Module title (German)	Topics of Current Research IV
Module title (English)	Topics of Current Research 4
Person responsible for the module	N.N.
Prerequisites for admission to the module	none
Type of module (compulsory module, required elective module, elective module)	Required elective module M.Sc. Physics focus „Optics” Required elective module M.Sc. Photonics
Frequency of offer (how often is the module offered?)	At irregular intervals
Duration of module	1 semester
Module Components/Types of courses (lecture, practical course, lab, tutorial, exercise, seminar, internship, …)	Lecture: 2 h per week Exercise: 1 h per week
ECTS credits	4 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	120 h 45 h 75 h
Content	• Advanced topics of current research in optics and photonics.
Intended learning outcomes	• Introduction into a field of current ressearch as a basis for further study and research in this field; • Independent solution of Exercise problems; • Ability to acquire further knowledge by independent literature studies.
Prerequisites for admission to the module examination	Course exercises to be submitted; further information on the kind and scope will be given at the beginning of each semester.
Requirements for awarding credit points (type of examination)	Written or oral examination (100%) The form of the exam will be announced at the beginning of the semester.
Language of instruction	English

Modul **PAFMO099** Master thesis	
Module code	PAFMO099
Module title (German)	Masterarbeit Photonics
Module title (English)	Master thesis
Frequency of offer (how often is the module offered?)	Every semester
Duration of module	1 semester
ECTS credits	30 CP
Work load: - In-class studying - Independent studying (incl. preparations for examination)	360 h 0 h 360 h

Abbrevations:

Abbrevations of lectures

IL....	Inaugural lecture
WG....	Working group
AM....	Advanced module
Exh....	Exhibition
BM....	Basic module
BzPS....	Begleitveranstaltung zum Praxissemester
C....	Consulting
To....	Tour
M....	Meeting
Blo....	Blockage
BC....	Block course
DV....	Slide show
IN....	Introductory session
RS....	Registrations
EC....	Exam course
EX....	Excursion
Exp....	Experiment/survey
FE....	Celebration/festivity
MS....	Movie screening
FEx....	Field exercise
BC....	Basic course
MaS....	Main seminar
MS/ BC....	Main seminar/block course
MaS/ Ex....	Main seminar/exercise
Inf....	Information session
IDS/E....	Interdisciplinary main seminar/exercise
E....	Exam
E/T....	Exam/test
C....	Colloquium
C/I....	Colloquium/practical work
CS....	Conference/symposium
kV....	Kulturelle Veranstaltung
Co....	Course
Cu....	Course

Abbrevations of lectures

Lag....	Lagerung
TRP....	Training research project
RC....	Reading course
M....	Module
ME....	Musical event
AS....	Advanced seminar
OnS....	Online seminar
OnL....	Online lecture
P....	Practical work
I/S....	Practical work/seminar
PM....	Practice module
Sa....	Sample
PJ....	Project
PPD....	Propaedeutic
PS....	Proseminar
EPr....	Exam preparation
CSA....	Cross-sectional area
RE....	Revision course
LS....	Lecture Series
TC....	Training course
S....	Seminar
S/E....	Seminar/Excursion
S/E....	Seminar/Exercise
ST....	Service time
SI....	Conference
SuSch....	Summer school
MISC....	Miscellaneous
OE....	Other event
LC....	Language course
Con....	Convention
TT....	Teleteaching
MN....	Meeting
Tu....	Tutorial
T....	Tutorial
E....	Exercise
E/BC....	Exercise/block course
E....	Exercises
E/I....	Exercise/interdisciplinary
E/I....	Exercise/practical work
E/T....	Exercise/tutorial

Abbrevations of lectures

Conf....	Conference
ViCo....	Video conference
L....	Lecture
L/C....	Lecture with colloquium
L/I....	Lecture/practical work
L/S....	Lecture/seminar
L/E....	Lecture/exercise
TK....	Talk
Sp....	Speech
OS....	Optional seminar
OL....	Optional lecture
Tr....	Training
WOS....	Workshop
Wo....	Workshop
CAC....	Certificate award ceremony

Other Abbrevations

Anm.....	Anmerkung
ASQ....	Allgemeine Schlüsselqualifikationen
AT....	Altes Testament
E....	Essay
FSQ....	Fachspezifische Schlüsselqualifikationen
FSV....	Fakultät für Sozial- und Verhaltenswissenschaften
GK....	Grundkurs
IAW....	Institut für Altertumswissenschaften
LP....	Leistungspunkte
NT....	Neues Testament
SQ....	Schlüsselqualifikationen
SS....	Sommersemester
SWS....	Semesterwochenstunden
TE....	Teilnahme
TP....	Thesenpublikation
ThULB....	Thüringer Universitäts- und Landesbibliothek
VVZ....	Vorlesungsverzeichnis
WS....	Wintersemester