Module Catalogue of the Faculty of Physics and Astronomy for the Master of Sciences (M.Sc.) Degree Program in Photonics 30th March, 2012

This module catalogue contains all compulsory and elective courses according to the examination regulations. The description of the courses contains information about the module coordinator, requirements for attendance, module type, work load, credit points, contents, objectives, and type of examination.

The module catalogue is in accordance with the conditions of the study course Photonics and will be updated every semester. The modules are in mainly in English.

Contents

Curriculum of the course Photonics, with the qualification Master of Science

ASP - Abbe School of Photonics **Friedrich-Schiller-Universität Jena**

Master Program Photonics — ECTS CP Σ 120

Adv. - Advised course
Comp. - Compulsory course
Elect. - Elective course
(G) - Course given in German

Version: 30.03.2012

1. Semester — 30 CP — Fundamentals & Adjustment

Module Fundamentals — Tünnermann — 8 CP (1. Semester) + 8 CP (2. Semester)

Opt. metrology & sensing	Kowarschik	Comp.	2L+1E	4 CP
Optical mod. & design I	Zeitner/Wyrowski	Comp.	2L+1E	4 CP

Module Adjustment — Paulus — 16 CP

Fundam. of modern optics	Skupin	Adv.	4L+2E	8 CP
Structure of matter	Meyer	Adv.	4L+2E	8 CP
Condensed matter physics (G)	Seidel	Adv.	4L+2E	8 CP

Module Labworks — Nolte — 6 CP

Labworks optics	University (Shipulin)	Comp.	6Lab	6 CP

2. Semester — 30 CP — Fundamentals & Specialization

Module Fundamentals (continued) — 8 CP

Laser physics	Tünnermann/Limpert/Nolte	Comp.	4L+2E	8 CP

Module Specialization I — Spielmann — 12 CP

Applied laser technology I	Stafast/Paa	Elect.	2L+1E	4 CP
Biophotonics	Heintzmann/Heinemann/..	Elect.	2L+1E	4 CP
Coherence theory and applic.	Kowarschik	Elect.	2L+1E	4 CP
Computational photonics	Pertsch	Elect.	2L+1E	4 CP
Design&corr. of opt. systems	Gross	Elect.	2L+1E	4 CP
Fiber optics	Bartelt	Elect.	2L+1E	4 CP
Fourier transform/sampling	Wyrowski	Elect.	2L+1E	4 CP
Holography	Kowarschik	Elect.	2L+1E	4 CP
Image processing	Denzler	Elect.	2L+1E	4 CP
Introduction to nanooptics	Pertsch	Elect.	2L+1E	4 CP
Micro/nanotechnology	Zeitner	Elect.	2L+1E	4 CP
Nonlinear optics	Skupin	Elect.	2L+1E	4 CP
Optical mod. & design II	Wyrowski	Elect.	2L+1E	4 CP
Optoelectronics	Schmidl	Elect.	2L+1E	4 CP
Physic. aspects of med. imag.	Reichenbach/Förster	Elect.	2L+1E	4 CP
Plasma physics	Kaluza	Elect.	2L+1E	4 CP
Quantum optics	Rockstuhl	Elect.	2L+1E	4 CP
Waveguide theory	Skupin	Elect.	2L+1E	4 CP

Module Internship — Nolte — 10 CP

Internship	Industry (/University)	Comp.	10Lab	10 CP

3. Semester — 30 CP — Specialization & Research

Module Specialization II — Lederer — 12 CP

Applied laser technology II	Stafast/Paa	Elect.	2L+1E	4 CP
Astrophotonics	Minardi/Pertsch	Elect.	2L+1E	4 CP
Biomedical imaging	Reichenbach/Förster	Elect.	2L+1E	4 CP
High-intensity/relativ. optics	Kaluza	Elect.	2L+1E	4 CP
Lasers in ophthalmo.&medic.	Heisterkamp	Elect.	2L+1E	4 CP
Microoptics	Bartelt	Elect.	2L+1E	4 CP
Nanomaterials & optical appl.	Grange/Pertsch	Elect.	2L+1E	4 CP
Nanoengineering	Schubert/Hoeppener	Elect.	2L+1E	4 CP
Nonlinear optics	Paulus	Elect.	2L+1E	4 CP
Optical mod. & design III	Wyrowski	Elect.	2L+1E	4 CP
Photovoltaics	Falk	Elect.	2L+1E	4 CP
Theoretical nanooptics	Rockstuhl/Pertsch	Elect.	2L+1E	4 CP
Thin film optics	Tünnermann/Stenzel	Elect.	2L+1E	4 CP
Ultrafast optics	Nolte	Elect.	2L+1E	4 CP

Module Research Labworks — Kaluza — 18 CP

Research labworks optics	University/Industry	Comp.	18Lab	18 CP

4. Semester — 30 CP — Research

Module Master Thesis — Kowarschik — 30 CP

Master thesis	University/Industry	Comp.	30Lab	30 CP

CP - Credit points; L - Lecture (hours/week); E - Exercise (hours/week); Lab - Labwork (hours/week), (G) – course given in German

Modules generally consist of a number of submodules. The ECTS points for a module correspond to the sum of ECTS points attributed to the submodules, which are required to be taken in the module. ECTS points for a module will only be granted, if the requirements in all assigned submodules are fulfilled.

Master exam after four semesters ≥ 120 CP

To start the master thesis work the three practical courses (Labwork optics, Internship, and Research labwork optics) have to be finished and a sum of 72 credit points is needed.

Advised courses

1. Semester; Module “Adjustment”

Number	ASP_MP_A1
Name	Adjustment
Coordinator	Prof. Dr. Gerhard G. PAULUS
Learning objectives	The *Adjustment* module provides and strengthens the fundamental knowledge in modern optics and condensed matter physics, which is required to follow the other parts of the Photonics program. Since students with different background are accepted into this Master program, different learning objectives will be advised to the individual students to overcome existing deficiencies or to strengthen already existing well developed fundamentals.
Content	The previous knowledge of each individual student will be carefully analyzed and a specific selection of 2 submodules will be advised to each student, out of the list of the offered submodules. Students, which had only a weak exposure to optics will be advised to take a submodule on fundamental optics. Similarly, a weak previous exposure to condensed matter physics will be compensated by a submodule on the structure of matter specifically designed to overcome this deficiency. Students with an already strong background in modern optics and/or condensed matter physics will be provided advice about more advanced optional submodules (e.g. advanced quantum mechanics or semiconductor physics) according to their level of knowledge. Students will know the fundamentals of photonics. They are enabled to follow more specialized courses in photonics.
Course type	lectures: 8 hours per week exercises: 4 hours per week organized as 2 individual submodules
ECTS credits	16
Category	Compulsory module with an ensemble of submodules, which will be advised to each student individually by the module coordinator according to the student’s previous knowledge. The module coordinator’s judgment will be based on the student’s transcripts as well as a personal interview.
Usability	basic module for the study in Photonics in the 1st semester
Frequency of offer	winter semester
Duration	1 semester
Work load	480h divided in lectures: 120h, exercises: 60h, self study: 300h
Language	generally English, some submodules are temporarily offered in German
Prerequisites	successful completion of Bachelor in a related field
Exam prerequisites	specifically defined for the individual submodules
Requirements to obtain ECTS points	The successful completion of 2 submodules is required, as defined in the submodules. The final grade will be determined as the mean of the grades obtained in the submodules, weighted by the ECTS points assigned to each submodule.
Used media	specifically defined in the description of the individual submodules
Literature	specifically defined in the description of the individual submodules

1. Semester; Submodule "Fundamentals of modern optics"

Number	ASP_MP_A1.1
Name	Fundamentals of modern optics
Coordinator	Prof. Dr. Thomas PERTSCH
Learning objectives	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.
Content	- geometrical optics, imaging - basic concepts of wave optics - dielectric function, Drude model, Kramers-Kronig - propagation of beams and pulses - diffraction theory - elements of Fourier optics - polarization of light - light in structured media - optics in crystals
Course type	lectures: 4h/week exercises: 2h/week
ECTS credits	8
Category	submodule which may be advised compulsory to a student according to the student's previous knowledge
Usability	submodule being part of module Adjustment for the study in Photonics in the 1st semester
Frequency of offer	winter semester
Duration	1 semester
Work load	240h divided in lectures: 60h, exercises: 30h, self study: 150h (90h lectures and exercises, 30h computer-based solving of physical problems, 30h exam preparation)
Language	English
Prerequisites	elements of linear algebra and calculus successful completion of Bachelor in a related field
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete submodule	written examination at the end of the semester (90 min duration)
Used media	blackboard, overhead projector, computer demonstrations
Literature	- B.E.A. Saleh and M.C. Teich, Fundamentals of Photonics - H.Lipson, D.S.Tannhauser, und S.G.Lipson, Optical Physics - E.Hecht and A.Zajac, Optics - F. L. Pedrotti, L. S. Pedrotti, L. M. Pedrotti, Introduction to Optics

1. Semester; Submodule "Structure of Matter"

Number	ASP_MP_A1.2
Name	Structure of Matter
Coordinator	Prof. Dr. Stefan SKUPIN
Learning Objectives	The course is an introduction to principles of condensed matter physics and imparts the fundamental knowledge on solid state physics and its impacts on optics. After completion of the course students should be able to understand the interrelation of solid state and photonic technologies and to actively apply this knowledge for their further studies and scientific work.
Content	- crystal binding - structure of solids - lattice dynamics - electrons in solids - thermal properties - semiconductor crystals - dielectrical and optical properties
Course type	lectures: 4h/week exercises: 2h/week
ECTS credits	8
Category	submodule may be advised to the student according to the student's previous knowledge
Usability	submodule is part of the module "Adjustment" in the 1st semester in the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 60h exercises: 30h self study: 150h - 45h (lectures) - 60h (exercises) - 45h exam preparation total Work load: 240h
Language	English
Prerequisites	successful completion of Bachelor in a related field
Exam prerequisites	regular participation in lectures and exercises
Requirement to complete submodule	written examination at the end of the semester (90 min duration)
Used media	blackboard and projector
Literature	- C. Kittel, Introduction to Solid State Physics, Wiley & Sons, Hoboken NJ, 2004 - M. P. Marder, Condensed Matter Physics, Wiley-Interscience, 2000 - N. W. Ashcroft and N. D. Mermin, Solid State Physics, Brooks Cole, 1976 - S. Hunklinger, Festkörperphysik, Oldenbourg, München, 2007

1. Semester; Submodule "Condensed matter physics (G)"

Number	ASP_MP_A1.3
Name	Condensed matter physics (G)
Coordinator	Prof. Dr. Paul SEIDEL
Learning objectives	The aim of this course is to provide basic skills for describing, modeling and measuring of structures, effects, phenomena and excitations in experimental condensed matter. After the course the students should be able to solve physical problems from this field.
Content	- Dynamics of the crystal lattice - Phonons and thermal properties - Electrons in condensed matter, electric properties - Dielectric properties - Magnetism - Supraconductivity - non-crystaline condensed matter - thin films
Course type	lectures: 4h/week exercises: 2h/week
ECTS credits	8
Category	submodule may be advised compulsory to the student according to the student's previous knowledge
Usability	submodule is part of the module "Adjustment" in the 1st semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 60h exercises: 30h self study: 150h - 45h (lectures) - 60h (exercises) - 45h exam preparation total work load: 240h
Language	German
Prerequisites	successful completion of Bachelor in a related field
Exam prerequisites	regular participation in lectures and exercises
Requirement to complete submodule	written examination at the end of the semester
Used media	Blackboard, computer presentations
Literature	- Ch. Kittel, Einführung in die Festkörperphysik, Oldenbourg, München - Bergmann/Schäfer, Festkörper (Lehrbuch der Experimentalphysik Bd. 6), W. de Gruyter, Berlin 2005

Compulsory courses

1. and 2. Semester; Module "Fundamentals"

Number	ASP_MP_F1
Name	Fundamentals
Coordinator	Prof. Dr. Andreas TÜNNERMANN
Learning objectives	The *Fundamentals* module provides and strengthens the fundamental knowledge in essential fields of modern optics, which is required to follow the more specialized parts of the Photonics program.
Content	The module contains courses on basic subjects of modern optics which includes optical measurement techniques, optical modeling techniques, design strategies, and laser physics. These courses deliver fundamental knowledge in this field, which should be common to all students in the field of optics and photonics. This fundamental knowledge can later be extended in the *Specialization* modules.
Course type	lectures: 8 hours per week exercises: 4 hours per week organized as 3 individual submodules
ECTS credits	16
Category	Obligatory module with an ensemble of compulsory submodules
Usability	basic module for the study in Photonics in the 1st and 2nd semester
Frequency of offer	winter semester and summer semester
Duration	2 semesters
Work load	lectures: 120 h exercises: 60 h self study: 300 h (lectures, exercises) total workload: 480 h
Language	English
Prerequisites	successful completion of Bachelor in a related field
Exam prerequisites	specifically defined for the individual submodules
Requirements to obtain ECTS points	The successful completion of 3 submodules is required, as defined in the submodules. The final grade will be determined as the mean of the grades obtained in the submodules, weighted by the ECTS points assigned to each submodule.
Used media	specifically defined in the description of the individual submodules
Literature	specifically defined in the description of the individual submodules

1. Semester; Submodule "Optical metrology and sensing"

Number	ASP_MP_F1.1
Name	Optical metrology and sensing
Coordinator	Prof. Dr. Richard KOWARSCHIK
Learning objectives	The course covers important methods of optical length measurement including the measurement of shape and shape deviations. Starting with the basic physical principles of these methods the main topic of the lecture is the discussion of their application in various fields of science and technology.
Content	- Two- and multi-beam interferometry - Wave-front analysis - Methods of phase measurement - White-light interferometry - Phase conjugation - Holography and holographic interferometry - Fringe projection - Triangulation
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	compulsory submodule
Usability	submodule being part of module *Fundamentals* for the study in Photonics in the 1st semester
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study : 45 h (lectures, exercises) 30 h solving of physical problems 15 h exam preparation total workload: 120 h
Language	English
Prerequisites	successful completion of Bachelor in a related field
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester (90 min duration)
Used media	blackboard, overhead projector, computer based demonstrations, written supplementary material
Literature	- E. Hecht, Optics - Born/Wolf, Principles of Optics

1. Semester; Submodule "Optical modeling and design I"

Number	ASP_MP_F1.2
Name	Optical modeling and design I
Coordinator	Prof. Dr. Frank WYROWSKI and PD Dr. Uwe ZEITNER
Learning objectives	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.
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
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	compulsory submodule
Usability	the submodule is part of the module *Fundamentals* of the Master of Photonics program in the 1st semester
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self study: - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
ECTS credits	4
Prerequisites	successful completion of Bachelor in a related field
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester
Used media	Blackboard, projector, PC Pool, PowerPoint, VirtualLab, Zemax
Literature	- 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

2. Semester; Submodule "Laser Physics"

Submodule number	ASP_MP_F1.3
Submodule name	Laser Physics
Submodule coordinator	Prof. Jens LIMPERT, and Prof. Stefan NOLTE
Learning objectives	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.
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
Course type	lectures: 4h/week exercises: 2h/week
ECTS credits	8
Category	compulsory submodule
Usability	the submodule is part of the module *Fundamentals* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 60h exercises: 30h self-study: 150h - 90h (lectures, exercises) - 60h oral presentation total work load: 240h
Language	English
Prerequisites	successful completion of Bachelor in a related field
Exam prerequisites	regular participation in lectures and exercises
Requirement to complete this submodule	oral representation and written examination at the end of the semester
Used media	Blackboard, overhead projector, computer based demonstrations, written supplementary material
Literature	- A. 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

Elective courses

2. Semester; Module "Specialization I"

Number	ASP_MP_S1
Name	Specialization I
Coordinator	Prof. Dr. Christian SPIELMANN
Learning objectives	The first specialization module allows defining and following individual education objectives of the students. In a selected number of topics out of the broad field of modern optics, the students should acquire a deep knowledge which makes them experts in a state of the art field of photonics. In this particular field the students should be facilitated to work immediately after graduation at very high level in science or application.
Content	Based on the students individual choice the module consists of 3 submodules out of the offered submodules on different topic of modern optics and photonics. The content of the individual submodules is defined in the submodule description. In general the module contains submodules on state of the art research and application fields of optics/photonics. Each submodule will provide an overview about a particular field together with a selection of specific theoretical and experimental methods necessary to perform research and development in this field.
Course type	lectures: 6 h/week exercises: 3 h/week organized in 3 individual submodules
ECTS credits	12
Category	Obligatory module consisting of 3 out of the offered submodules which must be selected by each student individually according to learning objectives of the student. The students will be guided in their selection.
Usability	specialization module for the study in Photonics in the 2nd semester
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 90 h exercises: 45 h self study: 225 h (lectures, exercises) total workload: 360 h
Language	English
Prerequisites	fundamental knowledge on modern optics and condensed matter physics as usually obtained in the modules Adjustment and Fundamentals 1
Exam prerequisites	specifically defined for the individual submodules
Requirements to obtain ECTS points	The successful completion of 3 submodules is required, as defined in the submodules. The final grade will be determined as the mean of the grades obtained in the submodules, weighted by the ECTS points assigned to each submodule.
Used media	specifically defined in the description of the individual submodules
Literature	specifically defined in the description of the individual submodules

2. Semester; Submodule "Applied laser technology I (Laser as a probe)"

Submodule number	ASP_MP_S1.1
Submodule name	Applied laser technology I –Laser as a probe
Submodule coordinator	Prof. Dr. Herbert STAFAST and Dr. Wolfgang PAA
Learning objectives	In a selected number of topics out of the broad field of laser applications, the students should acquire knowledge in laser diagnostics (remote and microscopic, cw and ultrafast), spectroscopy, metrology, and sensing.
Content	Applied Laser Technology using the laser as a probe for diagnostics (remote and microscopic, cw and ultrafast), spectroscopy, metrology, and sensing
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization I* according to the student's education objectives
Usability	submodule being part of module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises/seminars: 15 h self study : 75 h - 45 h (lectures, exercises) - 15 h solving of physical problems - 15 h exam preparation total workload: 120 h
Language	English
Prerequisites	Basic knowledge of lasers and general physics
Exam prerequisites	Successful participation in exercises/seminars
Requirement to complete this submodule	Successful completion of exercises /Seminar and exam (written or oral)
Used media	Media supports lectures and exercises/seminar
Literature	Laser Spectroscopy, W. Demtröder, Springer

2. Semester; Submodule "Biophotonics"

Submodule number	ASP_MP_S1.2
Submodule name	Biophotonics
Submodule noordinator:	Prof. Dr. Rainer HEINTZMANN, Prof. Dr. Stefan H. HEINEMANN, PD Dr. Roland SCHÖNHERR, Prof. Dr. Michael Schmitt, Dr. Kai WICKER
Learning objectives	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.
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..
Course type	lectures: 3h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	- lectures: 30h - exercises: 15h - self-study: 75h - exam preparation: 15h total work load: 135h
Language	English
Prerequisites	None
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	The form of the exam will be announced at the beginning of the semester. Either written examination at the end of the semester (60 min duration) or oral exam (15 min.)
Used media	blackboard, beamer, overhead projector, written supplementary material
Literature	- 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

2. Semester; Submodule "Coherence theory and applications"

Number	ASP_MP_S1.3
Name	Coherence theory and applications
Coordinator	Prof. Dr. Richard KOWARSCHIK
Learning objectives	In this course the students should learn how to understand and describe the coherence properties of classical optical fields and which information can be drawn from the measurement of coherence parameters.
Content	- Temporal and spatial coherence - Complex representation of polychromatic fields - Coherence function; degree of coherence - Propagation of the coherence function - Intensity correlation - Fourier spectroscopy - Transfer functions of coherent and incoherent systems - Resolution criteria - Wigner function
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules of module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester
Used media	blackboard, overhead projector, computer based demonstrations, written supplementary material
Literature	Born/Wolf, *Principles of Optics*

2. Semester; Submodule "Computational photonics"

Number	ASP_MP_S1.4
Name	Computational photonics
Coordinator	Prof. Dr. Thomas PERTSCH and Prof. Dr. Carsten ROCKSTUHL
Learning objectives	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 on different levels of approximation. The course concentrates predominantly on teaching numerical techniques that are useful in the field of micro- and nanooptics.
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
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module Specialization 1 according to the student's education objectives
Usability	submodule being part of module Specialization 1 for the study in Photonics in the 2nd semester
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study : 45 h (lectures, exercises) 15 h computer-based solving of physical problems 15 h exam preparation total workload: 120 h
Language	English
Prerequisites	fundamental knowledge on modern optics and condensed matter physics as usually obtained in the modules Adjustment and Fundamentals 1 as well as basic knowledge in a computer programming language and computational physics
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester (90 min duration)
Used media	blackboard and electronic presentations, computer based demonstrations, computer labs, written supplementary material
Literature	- A. Taflove and S.C. Hagness, Computational Electrodynamics - list of selected journal publications given during the lecture

2. Semester; Submodule "Design and correction of optical systems"

Number	ASP_MP_S1.5
Name	Design and correction of optical systems
Coordinator	Prof. Dr. Herbert GROSS
Learning objectives	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.
Content	- Basic technical optics - Paraxial optics - Imaging systems - Aberrations - Performance evaluation of optical systems - Measurement of system quality - Correction of optical systems - Optical system classification
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparations total work load: 120h
Language	English
Prerequisites	Fundamental knowledge on modern optics as usually obtained in the modules *Adjustment* and *Fundamentals I*
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	Written examination at the end of the semester
Used media	Blackboard and electronic presentations
Literature	- list of literature will be given during the lecture

2. Semester; Submodule "Fiber optics"

Number	ASP_MP_S1.6
Name	Fiber optics
Coordinator	Prof. Dr. Hartmut BARTELT
Learning objectives	This course introduces to the making and properties of different types of optical fiber waveguides. Applications of optical fibers to optical communication and optical sensing will be discussed.
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, dispersion compensating fibers) - Fiber devices (e.g. fiber amplifiers and lasers) - Applications in optical communication systems, optical sensor concepts
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparations total work load: 120h
Language	English
Prerequisites	Fundamental knowledge on modern optics and condensed matter physics as usually obtained in the modules *Adjustment* and *Fundamentals I*
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	Written or oral examination at the end of the semester
Used media	Blackboard and electronic presentations, computer based demonstrations, written supplementary material
Literature	- Calvo et al., Optical Waveguides - Snyder/Love, Optical Waveguide Theory - Okamoto, Fundamentals of Optical Waveguides

2. Semester; Submodule “Fourier transform and sampling theory”

Number	ASP_MP_S1.7
Name	Fourier transform and sampling theory
Coordinator	Prof. Dr. Frank WYROWSKI
Learning objectives	The Fourier transform (FT) is an essential tool in physical optics and optical modeling. This course presents the definition and theorems of the FT. Numerous important FT pairs are discussed. In modeling the discrete version of the FT is typically applied. It is derived and discussed. Sampling theory is another important issue in computational optics. It is closely related to the FT. The course introduces basic concepts of sampling theory and applies them to modeling problems in optics. Theoretical results are illustrated by computer simulations.
Content	- Definition of Fourier transform (FT) - Basic FT pairs - Properties of FT, including shift and convolution theorem - Complex signal - Sampling theory - Discussion of proper sampling of various important functions in optics - Development and discussion of discrete FT - Discrete convolution and correlation - Sampling of harmonic fields and its propagation
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester
Used media	Blackboard, projector, PC Pool, PowerPoint, VirtualLab, Mathematica
Literature	- The Fast Fourier Transform and its Applications by E. Oran Brigham, Prentice Hall - Mathematics of the Discrete Fourier Transform (DFT) by Julius O. Smith III, W3K Publishing

2. Semester; Submodule "Holography"

Number	ASP_MP_S1.8
Name	Holography
Coordinator	Prof. Dr. Richard KOWARSCHIK
Learning objectives	The course covers important methods of holography and their ability to record and reconstruct wavefields. Starting with the basic physical principles of these methods the main topic of the lecture is the discussion of their application in various fields of science and technology.
Content	- Holographic recording and reconstruction - Properties of holographic images - Types of holograms - Types of storage materials - Digital holography - Applications (storage and processing of information, holographic measuring techniques, 3D imaging, displays)
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules of module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester
Used media	blackboard, overhead projector, computer based demonstrations, written supplementary material
Literature	Ackermann/Eichler, *Holography,* Caulfield, *Handbook of Holography*

2. Semester; Submodule "Image processing"

Number	ASP_MP_S1.9
Name	Image processing
Coordinator	Prof. Dr. Joachim DENZLER
Learning objectives	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.
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
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written or oral examination at the end of the semester
Used media	Blackboard and electronic presentations
Literature	- Gonzalez, Woods, Digital Image Processing, Prentice Hall, 2001

2. Semester; Submodule "Introduction to nanooptics"

Number	ASP_MP_S1.10
Name	Introduction to nanooptics
Coordinator	Prof. Dr. Thomas PERTSCH
Learning objectives	The course aims at an introduction to the broad research field of nanooptics using an approach which is oriented on experiments. The students will learn about different concepts which are applied to control light at subwavelength spatial dimensions. Furthermore they will learn how light and nanostructures can be used to investigate physical phenomena with a spatial resolution not accessible with standard far field approaches to 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.
Content	The course will cover a basic introduction to the following topics: - Surface-plasmon-polaritons - Plasmonics - Technologies of nanooptics - Scanning nearfield optical microscopy - Photonic Nanomaterials / metamaterials - Optical nanoemitters
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module Specialization 1 according to the student's education objectives
Usability	submodule being part of module Specialization 1 for the study in Photonics in the 2nd semester
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study : 45 h (lectures, exercises) 15 h solving of physical problems 15 h exam preparation total workload: 120 h
Language	English
Prerequisites	fundamental knowledge on modern optics and condensed matter physics as usually obtained in the modules Adjustment and Fundamentals
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester (90 min duration)
Used media	blackboard and electronic presentations
Literature	- P. Prasad, Nanophotonics, Wiley 2004 - L. Novotny and B. Hecht, Principles of Nano-Optics, Cambridge 2006 - list of selected journal publications given during the lecture

2. Semester; Submodule "Micro/nanotechnology"

Number	ASP_MP_S1.11
Name	Micro/nanotechnology
Coordinator	PD Dr. Uwe ZEITNER
Learning objectives	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.
Content	The course will cover an introduction into the following topics: - 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
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in the module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration of submodule	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written or oral examination at the end of the semester (will be specified during the lecture)
Used media	blackboard and electronic presentations
Literature	will be announced during lectures

3. Semester; Submodule "Nonlinear optics"

Number	ASP_MP_S1.12
Name	Nonlinear optics
Coordinator	Prof. Dr. Stefan SKUPIN
Learning objectives	This course gives an introduction to optics in nonlinear media and discusses the main nonlinear effects.
Content	– Propagation of light in crystals – Properties of the nonlinear susceptibility tensor – Description of light propagation in nonlinear media – Parametric effects – Second harmonic generation – Phase-matching – Propagation of ultrashort pulses – High-harmonic generation - Relativistic optics
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization I* according to the student's education objectives.
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	Fundamentals of Modern Optics
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written or oral examination at the end of the semester
Used media	blackboard and electronic presentations, computer based demonstrations, written supplementary material
Literature	– Boyd, Nonlinear optics – Zernike/Midwinter, Applied nonlinear optics - Sauter, Nonlinear optics

2. Semester; Submodule "Optical modeling and design II"

Number	ASP_MP_S1.13
Name	Optical modeling and design II
Coordinator	Prof. Dr. Frank WYROWSKI
Learning objectives	In the second part of the lecture series on optical modeling and design techniques to propagate harmonic fields through optical components are presented. Together with the free-space propagation techniques (see part I) the students are enabled to trace harmonic fields through optical systems. In particular systems which combine classical components like lenses and prisms with micro-structured components like diffusers can be modeled by the presented techniques.
Content	- Modeling harmonic field propagation through plane interfaces and linear gratings - Modeling field propagation through layered media - Approximations for fields with small divergence (paraxial and parabasal) - Thin element approximation - Vectorial harmonic field propagation by geometrical optics - Concept of boundary operators - Vectorial modeling of focusing laser beams - Microscopy - Modeling and design of laser beam shaping systems
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester
Used media	Blackboard, projector, PC Pool, PowerPoint, VirtualLab
Literature	- E. Hecht and A. Zajac, Optics - M. Born and E. Wolf, Principles of Optics - L. Novotny and B. Hecht, Principles of Nano-Optics

2. Semester; Submodule "Optoelectronics"

Number	ASP_MP_S1.14
Name	Optoelectronics
Coordinator	PD Dr. Frank SCHMIDL
Learning objectives	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.
Content	- Waveguides - Semiconductors - Photodiodes - Light emitting diodes - Semiconductor optical amplifier
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving pf physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester
Used media	blackboard and electronic presentations
Lliterature	- list of selected publications given during the lecture

2. Semester; Submodule "Physical aspects of medical imaging and radiation therapy"

Submodule number	ASP_MP_S1.15
Submodule name	Physical aspects of medical imaging and radiation therapy
Submodule coordinator	Prof. Dr. J. R. Reichenbach / Prof. Dr. E. Förster
Learning objectives	The course introduces the physical principles, fundamental properties and technical concepts of imaging and therapy systems as they are applied today in medicine and physics. Applications, current developments as well as novel methods will be presented. At the end of the submodule students should demonstrate a critical understanding of the theoretical basis and technologies of these systems and have acquired an appreciation of instrumentation and practical issues with different imaging and therapy systems.
Content	• Introduction to imaging and therapy systems • Physical principles behind the design of selected biomedical imaging systems, including magnetic resonance imaging, ultrasound, and X-ray microscopy • Physical principles behind the design of selected radiation therapeutic systems • Novel laser-based sources of ion beams • Technological aspects of each modality • Importance of each modality concerning physical, biological and clinical applications
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module Specialization I in the 2nd semester of the Master of Photonics program
Frequency of offer	Summer semester
Duration	1 semester
Work load	Lectures and lab tours: 30h exercises: 15h self-study: 75h – 45h (lectures, exercises) – 15h solving of physical problems – 15h exam preparation total work load: 120h
Language	English
Prerequisites	None
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	oral examination
Used media	electronic presentations, computer based demonstrations, blackboard
Literature	- A. Oppelt, Imaging Systems for Medical Diagnostics: Fundamentals, Technical Solutions and Applications for Systems Applying Ionizing Radiation, Nuclear Magnetic Resonance and Ultrasound - Richter / Flentje (Eds.), Strahlenphysik für die Radioonkologie, Georg Thieme Verlag, Stuttgart, New York

2. Semester; Submodule "Plasma physics"

Number	ASP_MP_S1.16
Name	Plasma physics
Coordinator	Prof. Dr. Malte. KALUZA
Learning objectives	This course offers an introduction to the fundamental effects and processes relevant for the physics of ionized matter. After actively participating in this course, the students will be familiar with the fundamental physical concepts of plasma physics, especially concerning astrophysical phenomena but also with questions concerning the energy production based on nuclear fusion in magnetically or inertially confined plasmas.
Content	- fundamentals of plasma physics, - single particle and fluid description of plasmas, - waves in plasmas, - interaction of electromagnetic radiation with plasmas, - plasma instabilities - non-linear effects (shock waves, parametric instabilities, ponderomotive effects, ...)
Course type	lectures: 2h/week exercises: 2h every other week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module Specialization 1 according to the student's education objectives
Usability	submodule being part of module Specialization 1 for the study in Photonics in the 2nd semester
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study : 45 h (lectures, exercises) 15 h solving of physical problems 15 h exam preparation total workload: 120 h
Language	English
Prerequisites	Prior knowledge in electrodynamics is essential, knowledge in laser physics is recommended but not conditional.
Exam prerequisites	regular participation in lectures and active participation exercises
Requirements to complete this submodule	written or oral examination at the end of the semester (will be specified at the beginning of the lecture)
Used media	blackboard and electronic presentations
Literature	- F. Chen: Plasma Physics and Controlled Fusion, Plenum Publishing Corporation, New York (1984) - J. A. Bittencourt: Fundamentals of Plasma Physics, Springer, New York (2004) - U. Schumacher: Fusionsforschung, Wissenschaftliche Buchgesellschaft, Darmstadt (1993)

2. Semester; Submodule “Quantum optics”

Number	ASP_MP_S1.17
Name	Quantum optics
Coordinator	Prof. Dr. Holger GIES and Prof. Dr. Carsten ROCKSTUHL
Learning objectives	Acquiring knowledge about the concepts and methods to describe the quantized radiation field and the interaction of radiation and matter.
Content	Quantum properties of light Quantization of the electromagnetic field Light-matter interactions
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	Basics of electrodynamics, quantum mechanics, optics
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written or oral examination at the end of the semester (will be specified during lectures)
Used media	blackboard, electronic presentations
Literature	- M. Fox, Quantum Optics: An Introduction, - M. Lewenstein, A. Sanpera, M. Pospiech, Quantum Optics, an Introduction, Lecture Notes , U. Hannover, 2006 - D. D. Craig, T. T. Thirunamachandran, Molecular Quantum Electrodynamics - P. Meystre, M. Sargent, Elements of Quantum Optics, - D.-G. Welsch, Quantenoptik, Vorlesungsskript (in German).

2. Semester; Submodule "Waveguide theory"

Number	ASP_MP_S1.18
Name	Waveguide theory
Coordinator	Prof. Dr. Stefan SKUPIN
Learning objectives	The course aims at an introduction to the theory of guided waves
Content	- guided waves in 1D and 2D, basic theory - mode decomposition, orthogonality - weakly guiding waveguides - coupling of waveguides - pulses in waveguides
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module Specialization 1 according to the student's education objectives
Usability	submodule being part of module Specialization 1 for the study in Photonics in the 2nd semester
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study : 45 h (lectures, exercises) 15 h solving of physical problems 15 h exam preparation total workload: 120 h
Language	English
Prerequisites	fundamental knowledge on modern optics and condensed matter physics as usually obtained in the modules Adjustment and Fundamentals 1 as well as basic knowledge in a computer programming language and computational physics
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written or oral examination at the end of the semester (will be specified in the lecture)
Used media	blackboard and electronic presentations
Literature	- list of literature will be given during the lecture

2. Semester; Submodule "XUV and X-ray optics" (not offered in SS 2012)

Number	ASP_MP_S1.19
Name	XUV and X-ray optics
Coordinator	Prof. Dr. Christian SPIELMANN
Learning objectives	This course covers the fundamentals of modern optics at short wavelengths as they are necessary for the design of EUV and X-ray optical elements. Based on this the students will learn essentials of several challenging applications of short-wavelength optics, being actual in modern science and technology.
Content	- Complex refractive index in the XUV and X-ray range - Refractive and grazing incidence optics - Zone plate optics - Thomson and Compton scattering - X-ray diffraction by crystals and synthetic multilayers - VUV and X-ray optics for plasma diagnostics - Time-resolved X-ray diffraction - EUV lithography
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules of module *Specialization I* according to the student's education objectives
Usability	this submodule is part of the module *Specialization I* in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester (not offered in SS 2012)
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester
Used media	blackboard and electronic presentations
Literature	- list of literature will be given during the lecture

3. Semester; Module “Specialization II”

Number	ASP_MP_S2
Name	Specialization II
Coordinator	Prof. Dr. Falk LEDERER
Learning objectives	As in the first specialization module this module allows defining and following individual education objectives of the students. In a selected number of topics out of the broad field of modern optics the students should acquire a profound knowledge which makes them experts in a state of the art field of photonics and prepares them for the module *Master thesis.* In this particular field the students should be facilitated to work immediately after graduation at very high level in science or application.
Content	Based on the student´s individual choice the module consists of 3 out of the offered submodules on different topics of modern optics and photonics. The content of the individual submodules is defined in the submodule description. In general the module contains submodules on state of the art research and application fields of optics/photonics. Each submodule will provide an overview about a particular field together with a selection of specific theoretical and experimental methods necessary to perform research and development in this field.
Course type	lectures: 6h/week exercises: 3h/week organized in 3 individual submodules
ECTS credits	12
Category	Obligatory module consisting of 3 out of the offered submodules which must be selected by each student individually according to learning objectives of the student. The students will be guided in their selection.
Usability	Specialization module in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 90h exercises: 45h self-study: 225h (lectures, exercises) total work load: 360h
Language	English
Prerequisites	fundamental knowledge on modern optics and condensed matter physics as usually obtained in the modules *Adjustment* and *Fundamentals I*
Exam prerequisites	specifically defined for the individual submodules
Requirements to obtain ECTS points	The successful completion of 3 submodules is required, as defined in the submodules. The final grade will be determined as the mean of the grades obtained in the submodules, weighted by the ECTS points assigned to each submodule.
Used media	Specifically defined in the description of the individual submodules
Literature	Specifically defined in the description of the individual submodules

3. Semester; Submodule "Applied laser technology II (Laser as a tool)"

Number	ASP_MP_S2.16
Name	Applied Laser Technology II – Laser as a tool
Coordinator	Prof. Dr. Herbert STAFAST and Dr. Wolfgang PAA
Learning objectives	In a selected number of topics out of the broad field of laser applications, the students should aquire knowledge in laser-material interactions (e.g. optical tweezer), laser induced processes in gases, liquids, and matrices (incl. laser isotope separation), materials´ preparation and structuring by deposition, ablation and/or modification.
Content	- Applied Laser Technology using the laser as a tool (microscopic and macroscopic light-materials´ interactions, materials´ preparation and modifications.)
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	Basic knowledge of lasers and general physics
Exam prerequisites	Successful participation in exercises/seminar
Requirements to complete this submodule	Successful completion of exercises/seminar and exam (written or oral)
Used media	Media supported lectures and exercises/seminar
Literature	- Laser, Grundlagen und Anwendungen in Photonik, Technik, Medizin und Kunst, D. Bäuerle - Laseranwendungen, H.-G. Rubahn u. F. Balzer - Solid State Laser Engineering, W. Koechner

3. Semester; Submodule “Astrophotonics”

Number	ASP_MP_S2.15
Name	Introduction to applications of modern optics and photonics in astronomy
Coordinator	Dr. Stefano MINARDI and Prof. Dr. Thomas PERTSCH
Learning objectives	The lectures aim at presenting the emerging field of astrophotonics, i.e. photonics for astronomical instrumentation. Educational goals are: - familiarization with detection problematics in astronomy and - understanding of how photonic technology can solve them, usage of analytical tools for - modeling of photonic components and - system design of astronomical instruments.
Content	- Telescopes – Classification, adaptive optics, wavefront sensors. - Photometry – Exoplanet transits, photometric scales and bands in astronomy, semiconductor detectors, layer optics (coatings, filters), examples of instruments. - Interferometry – Optical astronomical interferometry: survey of results, principles of interferometric aperture synthesis, fiber optics, photonic beam combiners, fiber interferometers, pupil remapping, the photonic interferometer. - Spectroscopy – Historical introduction, Zeeman and Stark effects, Doppler shifts (binary systems, exoplanets, galaxies), review of dispersive elements, SWIFTS micro/nano spectrometers, AWGs, photon correlation spectroscopy, Multi-object and integral field spectroscopy, analysis of an instrument.
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester (90 min duration)
Used media	electronic presentations, computer based demonstrations, blackboard
Literature	- Saleh, Teich 'Photonics' Wiley - Journal articles from special issue on Astrophotonics in Optics Express (Vol. 17, issue 3, 2009) - Kitchin 'Astrophysical techniques' Ed. Adam Hilger - Bradt 'Astronomy methods' Cambridge - Roy & Clarke 'Astronomy: principles and practice' - Journal articles on astronomical instruments given during the lectures

3. Semester; Submodule "Biomedical imaging I"

Number	ASP_MP_S2.1
Name	Introduction to Imaging Systems in Physics and Medicine: Fundamentals and Applications
Coordinator	Prof. Dr.Jürgen R. REICHENBACH and Prof. Dr. Eckart FÖRSTER
Learning objectives	The course introduces the physical principles, fundamental properties and technical concepts of imaging systems as they are applied today in medicine and physics. The focus is laid on the use of ionizing radiation. 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 imaging systems and have acquired an appreciation of instrumentation and practical issues with different imaging systems.
Content	- Introduction to advanced 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
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	oral examination
Used media	electronic presentations, computer based demonstrations, blackboard
Literature	- A. Oppelt (Ed.), Imaging Systems for Medical Diagnostics: Fundamentals, Technical Solutions and Applications for Systems Applying Ionizing Radiation, Nuclear Magnetic Resonance and Ultrasound, Publicis, 2005 - P. Suetens, Fundamentals of Medical Imaging, 2nd ed., Cambridge University Press, 2009

3. Semester; Submodule "Computational material science"

Number	ASP_MP_S2.3
Name	Computational material science 1
Coordinator	Dr. Karsten HANNEWALD and Dr. Jürgen FURTHMÜLLER
Learning objectives	The aim of this course is to enhance the students' capabilities to solve various problems from different subfields in physics and materials science by means of numerical modeling, in particular, by writing short programs in C/C++.
Content	- vibrations and phonons (water molecules, quasi crystals) - solitons - hydrodynamics - phase transitions (percolation) - growth of clusters (fractals, random walk) - modeling of avalanches and earthquakes - parallelization of programs
Course type	exercises: 2h/week in the computer room
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	exercises: 30h self-study: 90h - 45h (exercises) - 30h solving of physical problems - 15 exam preparation total work load: 120h
Language	German
Prerequisites	knowledge in Solid State Physics
Exam prerequisites	regular participation in exercises
Requirements to complete this submodule	written examination at the end of the semester
Used media	blackboard, electronic presentations
Literature	- list of selected literature will be given during the lecture

3. Semester; Submodule "High intensity/relativistic optics"

Number	ASP_MP_S2.4
Name	High intensity/relativistic optics
Coordinator	Prof. Dr. Malte KALUZA
Learning objectives	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.
Content	- High-intensity laser technology - Laser plasma physics - Laser accelerated particles and applications
Course type	lectures: 2h/week exercises: 1h/week (will be given as 2h every second week)
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	oral or written examination at the end of the semester (will be specified at the beginning of the lecture)
Used media	blackboard, electronic presentations
Literature	- 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)

3. Semester; Submodule "Laser in ophthalmology and medicine"

Number	ASP_MP_S2.15
Name	Laser-Tissue Interaction and application of lasers in ophthalmology and medicine
Coordinator	Prof. Dr. Alexander HEISTERKAMP
Learning objectives	The students will be introduced to the basic mechanisms of laser-tissue interaction on the different time scales and laser intensities. The introduction of the different technologies will be accompanied by their application within different fields of clinical medicine, especially ophthalmology.
Content	Laser systems for the application in medicine Beam guiding systems and optical medical devices Optical properties of tissue Thermal properties of tissue Photochemical interaction Vaporisation/coagulation Photoablation Photodisruption, nonlinear optics Laser-based imaging Clinical applications Nanophotonics in medicine
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 30h studying and discussing recent publications, solving problems total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete submodule	written or oral examination, will be decided during semester
Used media	Blackboard, electronic slides, movies, pdf of recent publications
Literature	- Welch, van Gemert: "Optical-Thermal Response of Laser-Irradiated Tissue." Plenum Press; - Niemz: "Laser-tissue interaction", Springer; - Berlien: "Applied Laser Medicine" Springer; - list of publications given during the lecture.

3. Semester; Submodule "Microoptics"

Number	ASP_MP_S2.5
Name	Microoptics
Coordinator	Prof. Dr. Hartmut BARTELT
Learning objectives	The course covers specific optical properties of refractive and diffractive micro-structures as well as the propagation of light in free space and in optical waveguides. Scaling properties in optics are analyzed. The theory of optical waveguides is discussed, beginning with a comparison between the geometric or "ray optic" approach and the electromagnetic or "physical optic" approach. Fundamentals of dielectric and metallic artificial media including photonic crystals are provided. Materials, manufacturing and measurement techniques for microoptics are discussed.
Content	- Scaling properties in optics - Specific optical properties - Theory of guided light - Microoptical design - Materials and manufacturing techniques - Microoptical elements - Artificial media / Photonic crystals - System applications
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in the module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester
Used media	Blackboard, overhead projector, computer based demonstrations, written supplementary material
Literature	- Saleh/Teich, Fundamentals of Photonics, - Wehrspohn/Kitzerow/Busch, Nanophotonic Materials

3. Semester; Submodule "Nanomaterials and nanotechnology" (not offered in WS 2011/12)

Number	ASP_MP_S2.6
Name	Nanomaterials and nanotechnology
Coordinator	Prof. Dr. Carsten RONNING
Learning objectives	The students will adopt skills in the preparation and characterization of nanomaterials, as well as knowledge in the theoretical description of nanomaterials. They will learn methods in nanotechnology. Furthermore, the students will be trained in self-preparation of seminars.
Content	- Theory on dimensional effects - electronic quantization - single electron transistors - synthesis of nanomaterials - characterization of nanomaterials - material systems: carbon nanotubes, graphene, semiconductor materials, magnetic nanomaterials, bionanomaterials - applications and technology of nanomaterials
Course type	lectures: 2h/week seminar: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	every two year in winter semester
Duration	1 semester
Work load	lectures: 30h seminar: 15h self-study: 75h - 45h (lectures, seminar) - exam preparation total work load: 120h
Language	English or German
Prerequisites	Good knowledge in Solid State Physics
Exam prerequisites	regular participation in lectures
Requirements to complete this submodule	talk/seminar and written or oral exam
Used media	blackboard, electronic presentations, demonstration in laboratory
Literature	Springer Handbook of Nanotechnology (Editor: B. Bhushan), Basics of Nanotechnology (Wiley, H.G. Rubahn), Nanophysics and Nanotechnology (Wiley, E.L.Wolf), Mesoscopic Electronics in Solid State Nanostructures (Wiley, T. Heinzel)

3. Semester; Submodule "Nanomaterials and their optical applications"

Number	ASP_MP_S2.15
Name	Nanomaterials and their optical applications
Coordinator	Dr. Rachel GRANGE and Prof. Dr. Thomas PERTSCH
Learning objectives	The students will acquire knowledge in the synthesis and characterization of nanomaterials, as well as expertise in the optical characterization of nanomaterials. Furthermore, the students will be trained in preparation of seminars with state-of-the-art articles.
Content	- size effects: 3D down to 0D - synthesis of nanomaterials: top-down and bottom-up methods - material characterization: SEM, TEM, XRD, … - optical characterization methods: microscopy - material types: carbon nanotubes, graphene, semiconductor materials, magnetic nanomaterials, dielectric materials, bionanomaterials - functionalization of surfaces - safety issues of nanomaterials - plasmonics nanoshell - applications: nanooptofluidics, optical tweezing, nonlinear optics, optoelectronics, nanooptics, …
Course type	lectures: 2h/week seminar: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	every two year in winter semester
Duration	1 semester
Work load	lectures: 30h seminar: 15h self-study: 75h - 45h (lectures, seminar) - exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures
Requirements to complete this submodule	written or oral examination and participation in seminars as well as presentation in seminar
Used media	blackboard, electronic presentations, demonstration in laboratory
Literature	- Handbook of Nanotechnology by B. Bhushan (Springer) - Basics of Nanotechnology by H. G. Rubahn (Wiley) - Nanophysics and Nanotechnology by E. L. Wolf (Wiley) - Nanophotonics by P. N. Prasad (Wiley) - Squires, and Quake, Microfluidics: Fluid physics at the nanoliter scale, Rev. Mod. Phys. 77, 977 (2005)

3. Semester; Submodule "Nano engineering"

Number	ASP_MP_S2.7
Name	Nano Engineering
Coordinator	Dr. Stephanie HOEPPENER / Prof. Dr. Ulrich S. SCHUBERT
Learning objectives	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, mole¬cular self-assembly processes, chemical surface structuring, nanofabrica¬tion and surface chemistry to create a pool of knowledge to be able to use molecular building blocks in future research projects.
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
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	Submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h, exercises: 15h, self-study: 75 h (45h for lectures, exercises; 15h for assignments; 15h for exam preparation) total work load: 120h
Prerequisites	none
Exam prerequisites	Regular participation in lectures and exercises, assignments
Requirements to complete this submodule	Oral test
Used media	blackboard, electronic presentations
Literature	- 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.

3. Semester; Submodule "Nonlinear optics"

Number	ASP_MP_S2.8
Name	Nonlinear optics
Coordinator	Prof. Dr. Gerhard G. PAULUS
Learning objectives	This course gives an introduction to optics in nonlinear media and discusses the main nonlinear effects.
Content	– Propagation of light in crystals – Properties of the nonlinear susceptibility tensor – Description of light propagation in nonlinear media – Parametric effects – Second harmonic generation – Phase-matching – Propagation of ultrashort pulses – High-harmonic generation - Relativistic optics
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives.
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	Fundamentals of Modern Optics
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written or oral examination at the end of the semester
Used media	blackboard and electronic presentations, computer based demonstrations, written supplementary material
Literature	– Boyd, Nonlinear optics – Zernike/Midwinter, Applied nonlinear optics - Sauter, Nonlinear optics

3. Semester; Submodule "Optical modeling and design III"

Number	ASP_MP_S2.9
Name	Optical modeling and design III
Coordinator	Prof. Dr. Frank WYROWSKI
Learning objectives	In the third part of the lecture series on optical modeling and design modeling and design examples of micro and diffractive optics are discussed on the basis of the modeling techniques presented in parts I and II. Moreover, the finite element technique (FEM) is added to the collection of tracing techniques for harmonic fields. Then, the concept of field tracing is extended to general electromagnetic fields including temporal and spatial coherence and ultrashort pulses.
Content	- Modeling and design of lens arrays - Modeling and design of diffractive beam splitters - Modeling and design of diffusers - Finite element technique (FEM) - Representation of general fields by modal decomposition - Elementary mode decomposition: scalar and vectorial - Modeling polychromatic effects - Modeling effects of temporal and spatial coherence - Modeling ultrashort pulse propagation through optical systems - Efficient inclusion of material and angular dispersion
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester
Used media	Blackboard, projector, PC Pool, PowerPoint, VirtualLab
Literature	- E. Hecht and A. Zajac, Optics - L. Mandel and E. Wolf, Optical Coherence and Quantum Optics - B.E.A. Saleh and M.C. Teich, Fundamentals of Photonics

3. Semester; Submodule "Photovoltaics"

Number	ASP_MP_S2.11
Name	Photovoltaics
Coordinator	PD Dr. Fritz FALK
Learning objectives	The course is an introduction to the physical effects involved in photovoltaic energy conversion as well as in the technology of solar cell production. The student should learn to judge the effects influencing the loss mechanisms in solar cells in order to know what is important for increasing efficiency.
Content	- Introduction to the energy problem - Solar radiation - Principles of solar cells - Semiconductor physics I: equilibrium - Semiconductor physics II: non-equilibrium - Technology of thin film solar cells - Light trapping - Ideas for 4th generation solar cells
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and active participation in exercises
Requirements to complete this submodule	oral examination at the end of the semester
Used media	blackboard, overhead projector, manuscript in German available
Literature	- P. Würfel, Physics of Solar Cells - A. Lugue, S. Hegedus (Eds.), Handbook of Photovoltaik Science and Engineering - R. Enerlein, N. J. M. Horing, Fundamentals of Semiconductor Physics and Devices - M. D. Archer, R. Hill (Eds.), Clean Electricity from Photovoltaics

3. Semester; Submodule "Physics of free-electron lasers"

Number	ASP_MP_S2.10
Name	Physics of Free-Electron Lasers
Coordinator	Prof. Dr. Gerhard. G. PAULUS and Prof. Dr. Eckhart FÖRSTER and Dr. Ulf ZASTRAU
Learning objectives	The course introduces the physical principles, fundamental properties and technical concepts of the x-ray free electron laser (FEL). These unique machines consist of a linear electron accelerator and an periodic magnetic device, called undulator. Up to now, only few of these devices have been realized world-wide. They are capable of generating femtosecond x-ray pulses with paramount brightness. We will continue the course by highlighting the instrumentation needed for the pioneering experiments, comprising dense plasmas, molecule imaging, and ultrafast atomic physics. Finally, the first experiments that have been performed at FELs will be explained in detail. They open a door to a physical world that has been inaccessible until recently.
Content	- Introduction to physical principles of the FEL - Spatial and temporal properties of the FEL radiation - Physical principles behind the design of certain FEL like FLASH, LCLS, and the European XFEL - X-ray and XUV instrumentation for imaging and spectroscopy - Highlight experiments using unique properties of FELs
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd or 4th semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	oral examination
Used media	electronic presentations, computer based demonstrations, blackboard
Literature	- P. Schmüser, M. Dohlus, J. Rossbach, "Ultraviolet and Soft X-ray Free-Electron Lasers",Springer, 2008 - D. Attwood,"Soft X-rays and Extreme Ultraviolet Radiation", Cambridge University Press, 1999 - J. Als-Nielsen, D. McMorrow, "Elements of modern X-ray physics", Wiley 2001

3. Semester; Submodule "Theoretical nanooptics"

Number	ASP_MP_S2.12
Name	Theoretical nanooptics
Coordinator	Prof. Dr. Carsten ROCKSTUHL and Prof. Dr. Thomas PERTSCH
Learning objectives	The course outlines the theoretical concepts to describe light propagation in nanostructured optical materials and gives an introduction to the physical effects that can be observed in such materials.
Content	- Introduction to the general ideas of nanostructured materials - Physical effects in Photonics Crystals, metamaterials and plasmonic devices - Understanding light propagation using the concept of an eigenmode - Eigenmodes of periodic media - Dispersion relation of the periodic space and derived quantities - Scattering resonances of single objects - The concept of Hybridization to understand coupled particles - Determination of the effective parameters of metamaterials - Outline of numerical techniques for characterizing nanostructured materials - Contemporary problems in the field of nanooptics
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	fundamental knowledge on modern optics and condensed matter physics as usually obtained in the modules Adjustment and Fundamentals 1
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this submodule	written examination at the end of the semester (90 min duration)
Used media	blackboard and electronic presentations, computer based demonstrations, computer labs, written supplementary material
Literature	- Lukas Novotny und Bert Hecht, Principles of Nano-Optics, Cambridge University Press 2006 - Stefan A. Maier, Plasmonics: Fundamentals and Applications, Springer 2006 - John D. Joannopoulos et al., Photonic Crystals: Molding the Flow of Light, Princeton 2008

3. Semester; Submodule "Thin film optics"

Number	ASP_MP_S2.13
Name	Thin film optics
Coordinator	Prof. Dr. Andreas TÜNNERMANN and Dr. Olaf STENZEL
Learning objectives	This course is of use for anyone who needs to learn how optical coatings are used to tailor the optical properties of surfaces. After an introduction about the theoretical fundamentals of optical coatings the student should learn to calculate the optical properties of uncoated and coated surfaces. Based on this, typical design concepts and applications will be presented.
Content	- Introduction into optical material properties (classical description) - Theory of interference films - Thin film characterization methods - Design concepts - Types and application of optical coatings - selected questions of the semiclassical treatment of thin film spectra
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	Submodule which can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Prerequisites	Knowledge on optics and electrodynamics of continua
Exam prerequisites	Regular participation in lectures and exercises
Requirements to complete this submodule	oral or written test, depending on number of participants
Used media	blackboard, electronic presentations
Literature	- Born/Wolf: Introduction to optics - H. A. Macleod, Thin Film Optical Filters, Adam Hilger Ltd. 2001 - R. Willey, Practical Design and Productions of Optical Thin Films, Marcel Dekker Inc. 2003 - N. Kaiser, H. K. Pulker (Eds.), Optical Interference Coatings, Springer Series in Optical Sciences, Vol. 88, 2003 - O. Stenzel, The Physics of Thin Film Optical Spectra. An Introduction, Springer Series in Surface Sciences, Vol. 44, 2005

3. Semester; Submodule "Ultrafast optics"

Number	ASP_MP_S2.14
Name	Ultrafast optics
Coordinator	Prof. Dr. Stefan NOLTE
Learning objectives	The aim of this course is to provide a detailed understanding of ultrashort laser pulses, their mathematical description as well as their application. The students will learn how to generate, characterize and use ultrashort laser pulses. Special topics will be covered during the seminars.
Content	- Introduction to ultrafast optics - Fundamentals - Ultrashort pulse generation - Amplification of ultrashort pulses - Measurement of ultrashort pulses - Applications - Generation of attosecond pulses
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	submodule can be elected out of the list of offered submodules in module *Specialization II* according to the student's education objectives
Usability	this submodule is part of the module *Specialization II* in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30h exercises: 15h self-study: 75h - 45h (lectures, exercises) - 15h solving of physical problems - 15h exam preparation total work load: 120h
Language	English
Prerequisites	The students should have a basic understanding of laser physics and modern optics.
Exam prerequisites	regular participation in lectures and seminars
Requirements to complete submodule	written examination at the end of the semester
Used media	blackboard and overhead transparencies
Literature	- A. Weiner, Ultrafast Optics - Diels/Rudolph, Ultrashort Laser Pulse Phenomena - C. Rulliere, Femtosecond laser pulses - W. Koechner, Solid-state Laser engineering - A. Siegman, Lasers

Practical courses and internships

1. Semester; Module “Labworks”

Number	ASP_MP_L1
Name	Labworks
Coordinator	Prof. Dr. Stefan NOLTE and Dr. Arkadi SHIPULIN
Learning objectives	- 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.
Content	Practical training in optics. Topics cover a broad range, including refraction, optical lenses, interferometry, laser fundamentals, spectroscopy, optical tweezers, adaptive optics, etc.
Course type	practical course
ECTS credits	6
Category	obligatory module
Usability	module in the 1st semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	total work load: 180h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in all labworks
Requirements to obtain ECTS points	successful participation in all tests and acceptance of all written reports
Used media	
Literature	prepared electronic material describing the different labs The Material can be downloaded from www.asp.uni-jena.de.

2. Semester; Module “Internship”

Number	ASP_MP_I1
Name	Internship
Coordinator	Prof. Dr. Stefan Nolte
Learning objectives	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.
Content	Internship in industry or a research laboratory
Course type	practical course
ECTS credits	10
Category	obligatory module
Usability	module in the 2nd semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	total work load: 300h
Language	English
Prerequisites	
Exam prerequisites	Regular labwork
Requirements to obtain ECTS points	Written report and presentation of the results in a 20 – 30 minute talk
Used media	Specifically defined by the instructor of the internship
Literature	Specifically defined by the instructor of the internship

3. Semester; Module "Research Labwork"

Number	ASP_MP_RL1
Name	Research Labwork
Coordinator	Prof. Dr. Malte. KALUZA
Learning objectives	- Carrying out scientific labwork in optics together with a research team - Preparation of a scientific report - Presentation of the results in a written report
Content	internship in a research laboratory
Course type	practical course
ECTS credits	18
Category	obligatory module
Usability	module in the 3rd semester of the Master of Photonics program
Frequency of offer	winter semester
Duration	1 semester
Work load	total work load: 540h depending on the topic this total workload should be distributed approximately as: - 150 h introduction to the research topic (study of relevant literature, …) - 280 h research work (in the lab for experimental topics and at computer etc. for theoretical topics) - 100 h preparation of the final report (approximately 20-30 pages) - 10 h preparation and carrying out presentation of the results (20-30 minutes incl. discussion)
Language	English
Prerequisites	completion of the 2 practical modules Labwork and Internship
Exam prerequisites	regular labwork
Requirements to obtain ECTS points	written report and final presentation incl. discussion The final grade will be determined based on the research performance, the final report, and the presentation.
Used media	specifically defined by the instructor of the research team
Literature	specifically defined by the instructor of the research team

Master Thesis

4. Semester; Module “Master Thesis”

Number	ASP_MP_M
Name	Master Thesis
Coordinator	Prof. Dr. Richard KOWARSCHIK
Learning objectives	- Carrying out advanced scientific labwork in optics together with a research team - Preparation of the work flow and analysis of the results - Preparation of a scientific report - Presentation of the results in a master thesis and presentation
Content	internship in a research laboratory
Course type	practical course
ECTS credits	30
Category	obligatory module
Usability	module in the 4th semester of the Master of Photonics program
Frequency of offer	summer semester
Duration	1 semester
Work load	labwork: 450 h self-study: - 225 h preparation of experiments - 200 h writing of master thesis - 25 h preparation of final presentation total work load: 900h
Language	English
Prerequisites	72 ECTS points and the completion of the 3 practical modules *Labwork, Internship* and *Research Labwork*
Exam prerequisites	regular labwork
Requirements to obtain ECTS points	written report – Master's Thesis (66%), presentation (33%) Submission of a Master's Thesis. The results of the master’s thesis are presented by the candidate in a 20-30 minute talk, and then discussed. The final grade is determined according to the Rules of Examination (Prüfungsordnung).
Used media	specifically defined by the instructor of the research team
Literature	specifically defined by the instructor of the research team