Module Catalogue
for the Master of Science (M.Sc.) Degree Program in Medical Photonics

This catalogue contains a description of the modules of the Master of Science degree program in Medical Photonics. The program comprises five blocks:

- ***Adjustment***: Modules of this block provide students with the necessary background knowledge in natural sciences (with focus on optics and physical chemistry) and basic knowledge in biology and medicine (with focus on anatomy and physiology). Courses in this block are to be taken depending on the background of the student. Not all modules need to be chosen.
- ***Fundamentals***: This block provides students with basic skills needed in all other courses. All modules are compulsory.
- ***Specialization***: This block comprises elective courses the student can select to focus in more depth on a special topic.
- ***Practical training***: In all semesters theoretical courses and exercises are complemented by practical training in student and research laboratories.
- ***Master thesis***: The master thesis can be completed in university or industry research laboratories.

The program is complemented by language and soft skills courses offered by the Graduate Academy of the Friedrich-Schiller-University Jena.

Contents

1. Module Overview

The Master of Science degree program comprises the blocks *Adjustment*, *Fundamentals*, *Specialization*, *Practical training* and the master thesis.

1st semester Adjustment & Fundamentals	30 CP	2nd semester Adjustment & Fundamentals	30 CP	3rd semester Specialization & Research	30 CP	4th semester Research	30 CP

Legend :
compulsory courses
M = course is compulsory for students having a bachelor degree in biological sciences or having completed the basic studies in medicine
C = course is compulsory for students having a bachelor degree in chemical sciences
P = course is compulsory for students having a bachelor degree in physical sciences

Adjustment	16 CP		8 CP
Mathematical Methods (M/C) Precourse (3 weeks)	A0.1		
Mathematical Methods (M/C) 2L +2E	A1.1 4 CP	Physical Optics (M/C) 2L + 1E	A2.1 4 CP
Optical Engineering (M/C) 2L + 1E	A1.2 4 CP		
Physical Chemistry (M/P) 4L + 2E	A1.3 8 CP	Light Matter Interaction (M/P) 2L + 1E	A2.2 4 CP
Human Biology I (C/P) 4L + 2E	A1.4 8 CP	Human Biology II (C/P) 2L + 1E	A2.3 4 CP

Fundamentals	8 CP		8 CP
Image Processing I (M/C/P) 2L + 1E	F1.1 4 CP	Image Processing II (M/C/P) 2L + 1E	F2.1 4 CP
Biomedical Imaging I (M/C/P) 2L + 1E	F1.2 4 CP	Biomedical Statistics (M/C/P) 2L + 2E	F2.2 4 CP

Specialization	8 CP		12 CP
Basic techniques		Specialization towards microscopy	
Advanced mathematics 2L + 2E	S2.1 4 CP	Biological microscopy 2L + 1E	S3.1 4 CP
Biomedical Imaging II 2L + 1E	S2.2 4 CP	Single-molecule microscopy 2L + 1E	S3.2 4 CP
Microscopy 2L + 1E	S2.3 4 CP	Electron microscopy 2L + 1E	S3.3 4 CP
Lables (Dyes, Nanoparticles, etc.) 2L	S2.4 4 CP	Nanooptics 2L + 1E	S3.4 4 CP
Lasers in medicine 2L + 1E	S2.5 4 CP	Specialization towards clinical applications	
Fiber optics 2L + 1E	S2.6 4 CP	Ophthalmoscopy 2L + 1E	S3.5 4 CP
Image understanding 2L + 1E	S2.7 4 CP	Medical diagnosis and therapy 2L + 1E	S3.6 4 CP
Visual recognition and analysis 1L + 2E	S2.8 4 CP	Theranostics 2L + 1E	S3.7 4 CP
Management of scientific data 2L + 2E	S2.9 4 CP	Biomaterials 2L + 1E	S3.8 4 CP
		Specialization towards spectroscopy / diagnostics	
		Chemometrics 2L + 1E	S3.9 4 CP
		Microspectroscopy 3L	S3.10 4 CP
		Mass Spectrometry Imaging 2L + 1E	S3.11 4 CP
		Optical Sensors, Microfluidics 2L + 1E	S3.12 4 CP

Practical Training				
Practical Course	P1 12 CP	Research Labworks	P2 18 CP	Master Thesis	M 30 CP

2. Block Adjustment

2.1. Block A: Adjustment (1st and 2nd semester)

Block number	MedPho – A
Block name	Adjustment
Coordinators	Christoph BISKUP, Michael SCHMITT, Herbert GROSS
Learning objectives	This module block provides students with the necessary background knowledge in natural sciences (with focus on optics and physical chemistry) and basic knowledge in biology and medicine (with focus on human anatomy and physiology). Courses in this module are to be taken depending on the background of the student. Not all modules need to be chosen.
Content	Since students with different background are accepted to this Master program, different modules are advised. Students are supposed to take 2 out of 3 modules. The following modules are offered within this block: • Mathematical concepts (A1.1): The course (A1.1) focuses on basic mathematical concepts and methods that are important to analyze problems in optics or physical chemistry. To get prepared, students have the opportunity to attend an additional pre-semester-course (A0.1). Pre-course and course are strongly advised for students not having a Bachelor degree in mathematics or physics. Students of physics having passed the corresponding modules during their studies do not need to participate in this course. • Optics (Module A2.1): This Module provides an introduction into the fundamentals of optics and photonics. The module is mandatory for students not having a Bachelor degree in physics. Students of physics having passed the corresponding modules during their studies do not need to participate in this course. • Physical Chemistry (Module A1.2) + Light Matter Interaction (Module A2.2): These modules provide an introduction into the fundamentals of physical chemistry. Topics of module A1.2 include equilibrium thermodynamics, chemical kinetics and an introduction into molecular quantum mechanics (techniques of approximation). Topics of module A.2.2 include an introduction into molecular transitions, UV/Vis absorption spectroscopy, fluorescence spectroscopy, basic concepts of vibrational and rotational spectroscopy. These modules are mandatory for students not having a Bachelor degree in chemistry or physics. Students of chemistry or physics having passed the corresponding modules during their studies do not need to participate in this course. • Human biology (Modules A1.3 + A2.3): This course provides an introduction into the human anatomy and physiology. The medical histology part of the module will cover the microscopic structure of cells and tissues that make up the organ systems. In the macroscopic anatomy and physiology part of the course students will explore the major organ systems of the human body. These modules are mandatory for students not having a Bachelor degree in biomedical sciences. The modules may be advised to students having a Bachelor degree in biology. Students of medicine having passed the corresponding module during their studies do not need to participate at this course.
Course type	Lectures and exercises organized as 4 individual modules in 2 semesters, which have to be chosen depending on the knowledge of the student.
ECTS credits	16 ECTS credits in the 1st semester, 8 ECTS credits in the 2nd semester, 24 ECTS credits in total
Category	Based on the previous knowledge the modules will be advised to each student. The decision will be based on the student's transcript and a personal interview.
Usability	Basic module in the 1st and 2nd semester.
Frequency of offer	winter semester (1st part) + summer semester (2nd part)
Duration	2 semester
Work load	lectures: 180 h exercises: 90 h self study: 450 h total work load: 720 h
Language	English
Prerequisites	none
Exam prerequisites	specifically defined in the description of the individual modules
Requirements to complete this block	specifically defined in the description of the individual modules

Block number	MedPho – A
Used media	specifically defined in the description of the individual modules
Literature	specifically defined in the description of the individual modules

2.2. Pre-Course A 0.1: Mathematical Methods

Module number	MedPho – A 0.1
Module name	Mathematical Methods (Pre-course)
Coordinator, lecturers	Agnes SAMBALE
Learning objectives	Bachelor students of different disciplines have a different knowledge in mathematics depending on their education in school and their bachelor programme. This pre-course aims to review half-forgotten topics and complement the knowledge of the students, providing a foundation for the module "Mathematical concepts and methods" (Module A1.1).
Content	• Functions o concept of a function, graphical representations of functions o trigonometric functions o exponential, logarithmic and hyperbolic functions • Complex numbers o Definition and properties of complex numbers o Graphical representation of complex numbers o Exponential form of complex numbers o Operations with complex numbers • Vector algebra: o Scalars and vectors o addition and subtraction of vectors o scalar and vector products o basic matrix algebra o physical applications • Conic sections • Differential calculus o sequences and limits o differentiation of a function o curve sketching • Integral calculus o Fundamental theorem of the differential and integral calculus o The definite integral o Methods of integration o Applications: radioactive decay, Lambert-Beer's law • Power series • Other topics based on the student's needs
Course type	lectures: 20h/week (for 3 weeks) exercise: 20h/week (for 3 weeks)
ECTS credits	ECTS credit points will not be given for this course.
Category	This pre-course is not mandatory. It is, however, strongly advised to students having a weak background in mathematics.
Usability	The pre-course provides the theoretical basis for the module "Mathematical concepts and methods" (Module A1.1) and the module "Advanced Mathematics" (Module S2.1).
Frequency of offer	3 weeks before beginning of the winter semester
Duration	3 weeks
Work load	lectures: 4 h/day, total: 60 h exercises: 4 h/day, total: 60 h self study: 2 h/day, total: 30 h total work load: 150 h
Language	German / English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	none
Used media	lectures: blackboard, projector exercise: pen, paper
Literature	• Script given at the beginning of this pre-course • See list of books recommended for module A1.1

2.3. Module A 1.1: Mathematical Methods (1st semester)

Module number	MedPho - A 1.1
Module name	Mathematical Methods
Coordinator, lecturers	Agnes SAMBALE
Learning objectives	The course focusses on basic mathematical concepts and methods. The intention of this course is to give the students enough background so that they can cope successfully with the mathematics required to treat problems in optics or physical chemistry. Mathematical concepts presented in this course will be complemented by the modules "Image Processing I+II" (Modules F1.1/F2.1) and "Biomedical Statistics" (Module F2.2).
Content	• Differentiation of functions of two and more variables o Partial differentiation o Total differentiation o Taylor's theorem for many-variable functions o Applications: Thermodynamic relations • Differential equations o Concept and classification of differential equations o General solution of first-order and second-order differential equations o Applications of differential equations: harmonic oscillator
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	8
Category	This module is only mandatory for students of biology and medicine. It may be advised to students of chemistry having a weak background in mathematics. Students of physics having passed the corresponding modules during their studies do not need to participate at this course.
Usability	The module is part of the "Adjustment" block in the Medical Photonics program. This course provides the theoretical framework for other modules such as "Optical Engineering" (module A1.1) and "Physical Optics" (module A2.1).
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 30 h self study: 60 h total work load: 120 h
Language	German / English
Prerequisites	Good basic knowledge in mathematics. Students having a weak background in mathematics are strongly advised to visit the pre-course offered 3 weeks before the beginning of the winter term.
Exam prerequisites	regular participation at lectures and exercises, students must have earned in the exercises more than 50% of the available points
Requirements to complete this module	written examination
Used media	lectures: blackboard, projector exercise: pen, paper
Literature	• Script given at the beginning of the lecture • M.L. Boas: Mathematical Methods in the Physical Sciences. 3rd ed., John Wiley 2005. • K.F. Riley, M.P. Hobson: Essential Mathematical Methods for the Physical Sciences. Cambridge University Press 2011. • H. Schulz: Physik mit Bleistift: Das analytische Handwerkszeug der Naturwissenschaftler. • G.F. Simons: Calculus with Analytic Geometry, McGraw Hill 1996. • K. Weltner, S. John, W.J. Weber, P. Schuster, J. Grosjean: Mathematics for Physicists and Engineers. 2nd ed., Springer 2014

2.4. Module A 1.2: Optical Engineering (1st semester)

Module number	MedPho - A 1.2
Module name	Optical Engineering
Coordinator, lecturers	**Herbert GROSS**, Michael KEMPE, Maria DIENEROWITZ
Learning objectives	This module provides an introduction into the fundamentals of optics and photonics which are necessary to understand optical phenomena in modern science and technology. Topics include an introduction into the theory of light (ray optics, wave optics, electromagnetic optics, photon optics), the theory of interaction of light with matter and the theory of semiconductor materials and their optical properties.
Content	• Introduction to optics • Geometrical optics: postulates of ray optics, paraxial optics, matrix approach, raytracing • Simple optical components: lenses, mirrors, stops • Wave optics: postulates of wave optics, relation between wave optics and ray optics • Optical imaging: field and pupil, magnification, lens maker's formula, afocal systems • Photometry and illumination, color • Optical instruments • Image quality: primary aberrations, wave aberrations, correction of systems • Beam optics: the Gaussian beam, transmission of a Gaussian beam through optical components, beam shaping • Optical properties of materials: metals, ceramics, glass, polymers and composites • Electromagnetic optics: electromagnetic theory of light, dielectric media, elementary electromagnetic waves, absorption and dispersion • Optical components II: Fibers, prisms, sensors, aspheres, arrays • Special topics: scanning, adaptive optics, gradient index optics
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	The module is mandatory for students not having a Bachelor degree in physics. Students of physics having passed the corresponding modules during their studies do not need to participate in this course.
Usability	This module is part of the block „Adjustment" of the 1st semester.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	Lectures/excercises: blackboard, projector
Literature	• E. Hecht: Optics, 4th ed., Addison-Wesley 2001 • B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics 2nd ed., Wiley 2007.

2.5. Module A 1.3: Physical Chemistry (1st semester)

Module number	MedPho – A 1.3
Module name	Physical Chemistry
Coordinator, lecturers	**Michael SCHMITT**, Rainer HEINTZMANN, Jürgen POPP
Learning objectives	This module provides an introduction into the fundamentals of physical chemistry. Topics include equilibrium thermodynamics, chemical kinetics and an introduction into molecular quantum mechanics (techniques of approximation).
Content	• Equilibrium thermodynamics: Properties of gases, first and second law of thermodynamics, chemical equilibrium, equilibrium electrochemistry • Transport phenomena: molecular motion in gases and liquids, diffusion, transport across biological membranes • Chemical reactions: chemical kinetics, rate laws, temperature dependence of reaction rates, relaxation methods, kinetics of complex reactions • Basics of quantum mechanics: wavefunctions and operators, particle in a box, harmonic oscillator, particle on a sphere, rigid rotator • Approximations: variational principle, Born-Oppenheimer approximation, linear combination of atomic orbitals (LCAO) method, Hartree-Fock, density functional theory (DFT)
Course type	lectures: 4h/week exercises: 2h/week
ECTS credits	8
Category	The module is mandatory for students not having a Bachelor degree in chemistry or physics. Students of chemistry or physics having passed the corresponding modules during their studies do not need to participate in this course.
Usability	This module is part of the block „Adjustment“ of the 1st semester.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 60 h exercises: 30 h self study: 150 h (lectures + exercises: 120 h, exam preparation: 30h) total work load: 240 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	blackboard, beamer, overhead projector, written supplementary material
Literature	• Textbooks on physical chemistry: o P.W. Atkins, J. de Paula: Physical Chemistry. 9th ed., OUP Oxford 2009. • Textbooks on molecular quantum mechanics: o P.W. Atkins, R.S. Friedman: Molecular quantum mechanics. 5th ed., Oxford University Press 2010.

2.6. Module A 1.4: Human Biology I (1st semester)

Module number	MedPho - A 1.3
Module name	Human Biology I
Coordinator, lecturers	**Christoph BISKUP**, Ralf MROWKA, Hans-Georg SCHAIBLE, Alexander Berndt, Yuan Chen, Iver Petersen, Bernd Romeike
Learning objectives	This course provides an introduction into the human anatomy and physiology. The medical histology part of the module will cover the microscopic structure of cells and tissues that make up the organ systems. In the macroscopic anatomy and physiology part of the course students will explore the major organ systems of the human body. Students will gain an understanding of their structure, how they function, and which role they play for the whole organism.
Content	**Histology + Cellular Physiology** • cell morphology, tissue preparation, histochemistry, staining techniques • cellular physiology (genetic control of protein synthesis, cell cycle, cell reproduction, apoptosis) • types of tissues (classification, histogenesis of tissues, identification of tissues) • morphology and properties of epithelial tissues, connective tissue, cartilage, bone, muscle tissue and nerve tissue • membrane physiology (transport through membranes, membrane potentials, action potentials) • skeletal muscle (structure, neuromuscular junction, excitation-contraction coupling, contraction cycle) • smooth muscle (structure, nervous and hormonal control of smooth muscle contraction) • blood, hemopoiesis **Macroscopic Anatomy** • the skeleton (spine, skull, thorax, upper extremity, lower extremity, articulations) • muscles • vascular system • nervous system (brain, spinal cord, cranial nerves, spinal nerves) **Histology, macroscopic anatomy and physiology of organ systems** • cardiac physiology: ultrastructure and anatomy of the heart, action potential, excitatory and conductive system, heart sounds, electrocardiogram • cardiovascular system: histology of arteries, capillaries, veins, interrelationships of pressure, flow and resistance, humoral and nervous control of the circulation, regulation of blood pressure and blood volume • respiration: anatomy of nasal cavities, pharynx, larynx, trachea, bronchi, bronchioles, alveoli, mechanics of pulmonary ventilation, pulmonary volumes and capacities, alveolar ventilation, gas exchange, transport of oxygen and carbon dioxide in blood and tissue, regulation of respiration • digestive system: anatomy and physiology of the oral cavity (tongue, teeth, salivary glands), esophagus, stomach, small intestine, colon, rectum, liver, gallbladder, pancreas, metabolism of carbohydrates, proteins and lipids) • kidney and urinary system: histology and anatomy of the kidney, ureter, urinary bladder and urethra, renal physiology (renal blood flow, glomerular filtration, tubular reabsorption and secretion, regulation of extracellular fluid osmolarity and regulation of the extracellular volume, acid/base balance) • endocrine organs: anatomy and physiology of the hypothalamus, pituitary gland, thyroid gland, parathyroid glands, adrenal glands • skin: anatomy and physiology of the skin
Course type	lectures: 4h/week exercise: 2h/week
ECTS credits	8
Category	The modules Human Biology I + II are mandatory for students not having a Bachelor degree in biomedical sciences. The modules may be advised to students having a Bachelor degree in biology. Students of medicine having passed the corresponding module during their studies do not need to participate at this course.
Usability	The module is part of the block “Adjustment” in the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load (winter semester)	lectures: 60 h exercises: 30 h self study: 150 h (lectures: 45h, exercises: 60 h, exam preparation: 45h) total work load: 240 h

Module number	MedPho - A 1.3
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	lectures: blackboard, projector excercises: microscope, fixed specimens, cadaveric preparations, experimental setups provided by the Institute of Physiology
Literature	Microscopic and Macroscopic Anatomy • L.C. Junqueira, A.L. Mescher: Basic Histology: Text and Atlas. 12th ed., 2009. • R.L. Drake, W. Vogl, A.W.M. Mitchell: Gray's Anatomy for students. 2nd ed., Churchill Livingstone 2009. Physiology • W.F. Boron, E.L. Boulpaep: Medical Physiology. 2nd ed., Saunders/Elsevier, 2012. • A.C. Guyton, J.E. Hall: Textbook of Medical Physiology. 12th ed., Saunders 2010 • E.R. Kandel, J.H. Schwartz, T. Jessell: Principles of neural science. 4th ed., McGraw Hill 2000.

2.7. Module A 2.1: Physical Optics (2nd semester)

Module number	MedPho - A 2.1
Module name	Physical Optics
Coordinator, lecturers	**Herbert GROSS**, Maria DIENEROWITZ
Learning objectives	Together with module A1.2 this module provides an introduction into the fundamentals of optics and photonics which are necessary to understand optical phenomena in modern science and technology. Topics include an introduction into the theory of light (ray optics, wave optics, electromagnetic optics, photon optics), the theory of interaction of light with matter and the theory of semiconductor materials and their optical properties.
Content	• Coherence, interference, polychromatic light • Fourier optics: propagation of light in free space, optical Fourier transform • Diffraction, point spread function, modulation transfer function • Physical image formation, phase imaging • Image quality and resolution • Polarization and crystal optics: polarization of light, reflection and refraction, optics of anisotropic media, polarization devices • Photon optics: energy and momentum of a photon, time-energy uncertainty, photon streams, photon statistics • Diffracting components: gratings, diffractive optical elements (DOEs), arrays • PSF engineering, superresolution, extended depth of focus • Scattering and tissue optics
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	The module is mandatory for students not having a Bachelor degree in physics. Students of physics having passed the corresponding modules during their studies do not need to participate in this course.
Usability	This module is part of the block „Adjustment“ of the 2nd semester.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	Lectures/excercises: blackboard, projector
Literature	• E. Hecht: Optics, 4th ed., Addison-Wesley 2001 • B.E.A. Saleh, M.C. Teich: Fundamentals of Photonics 2nd ed., Wiley 2007.

2.8. Module A 2.2: Light-Matter Interaction (2nd semester)

Module number	MedPho – A 2.2
Module name	Physical Chemistry
Coordinator, lecturers	**Juergen POPP**, Michael SCHMITT, Rainer HEINTZMANN
Learning objectives	This module provides an introduction into the fundamentals of physical chemistry, which are necessary to understand modern spectroscopy. Topics include an introduction into molecular transitions, UV/Vis absorption spectroscopy, fluorescence spectroscopy, basic concepts of vibrational and rotational spectroscopy
Content	• Basic principles light-matter interaction: energy levels of atoms and molecules, energy bands in solid state materials, occupation of energy levels in thermal equilibrium, electrical properties of matter, dipole moment, polarisation, refractive index, electromagnetic radiation, classical dispersion theory, light scattering • Introduction into molecular spectroscopy: basic principles of the interaction of photons with atoms and molecules (selection rules, transition dipole moment, line width), microwave absorption spectroscopy, infrared absorption spectroscopy, UV/Vis absorption (Franck-Condon principle, electronic chromophores), fluorescence spectroscopy
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	The module is mandatory for students not having a Bachelor degree in chemistry or physics. Students of chemistry or physics having passed the corresponding modules during their studies do not need to participate in this course.
Usability	This module is part of the block „Adjustment“ of the 2nd semester.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 60 h, exam preparation: 15 h) total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	blackboard, beamer, overhead projector, written supplementary material
Literature	• Textbooks on physical chemistry: o P.W. Atkins, J. de Paula: Physical Chemistry. 9th ed., OUP Oxford 2009. • Textbooks on molecular quantum mechanics: o P.W. Atkins, R.S. Friedman: Molecular quantum mechanics. 5th ed., Oxford University Press 2010.

2.9. Module A 2.3: Human biology II (2nd semester)

Module number	MedPho - A 2.3
Module name	Human Biology II
Coordinator. lecturers	**Hans-Georg SCHAIBLE**, Andrea EBERSBERGER, Christoph BISKUP, Ralf MROWKA, Alexander Berndt, Yuan Chen, Iver Petersen, Bernd Romeike
Learning objectives	This course provides together with the Physiology I module an introduction into the human anatomy and physiology. The focus of this module is on neurophysiology.
Content	**Histology, macroscopic anatomy and physiology of the nervous system** • nerve, synapse, neurotransmitters • organization of the nervous system • autonomous nervous system • sensory physiology (sensory receptors, somatic sensations, pain) • vision (optics of the eye, photochemistry of vision, visual pathways) • hearing (tympanic membrane and ossicular system, cochlea, hearing pathways) • chemical senses (sense of taste, sense of smell) • motoric system (motoric functions of the spinal cord, cortical and brain stem control of motor function, cerebellum, basal ganglia) • limbic system, emotions • states of brain activity (eeg, sleep, epilepsy) • cerebral blood flow • endocrinology (general principles, hypothalamus, pituitary gland, thyroid hormones, adrenocaortical hormones, insulin, glucagon, parathyroid hormone, calcitonin, vitamin D)
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	The modules Human Biology I + II are mandatory for students not having a Bachelor degree in biomedical sciences. The modules are recommended to students having a Bachelor degree in biology. Students of medicine having passed the corresponding modules during their studies do not need to participate in this course.
Usability	The module is part of the block “Adjustment” in the Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	lectures: blackboard, projector exercise: experiments provided by the Institute of Physiology
Literature	See Module A1.4 for a detailed list of recommended textbooks

3. Block Fundamentals

3.1. Block F: Fundamentals (1st and 2nd semester)

Block number	MedPho – F
Block name	Fundamentals
Coordinators	Christoph BISKUP, Rainer HEINTZMANN, Herbert GROSS
Learning objectives	In this block the necessary fundamental knowledge in essential fields of optics and image processing is taught. The modules provide the students with the basics needed for the more specialized courses in the following semesters.
Content	Courses within this block provide an introduction into basic principles of data and image analysis: • Programming and Image Processing (Modules F1.2 + F2.1) • Statistics (Module F2.2) The following courses provides an introduction into basic biomedical imaging techniques: • Biomedical imaging I (Module F1.2)
Course type	lectures: 4h/week during the 1st semester, 4h/week during the 2nd semester exercises: 2h/week during the 1st semester, 2h/week during the 2nd semester organized as 4 individual modules in 2 semesters
ECTS credits	8 ECTS credits in the 1st semester, 8 ECTS credits in the 2nd semester
Category	The modules of this block are mandatory.
Usability	Basic module in the 1st and 2nd semester.
Frequency of offer	winter semester (1st part) + summer semester (2nd part)
Duration	2 semester
Work load	lectures: 120 h exercises: 60 h self study: 360 h total work load: 480 h
Language	English
Prerequisites	none
Exam prerequisites	specifically defined in the description of the individual modules
Requirements to complete this block	The successful completion of 2 modules/semester (4 modules in total) is required.
Used media	specifically defined in the description of the individual modules
Literature	specifically defined in the description of the individual modules

3.2. Module F 1.1: Image processing I (1st semester)

Module number	MedPho - F 1.1
Module name	Image Processing I
Coordinator, lecturers	**N.N. (Carl Zeiss professor)**, Christoph BISKUP, Rainer HEINTZMANN,
Learning objectives	MATLAB is a high-level language and interactive environment for numerical computation, visualization, and programming. This course will give an introduction into MATLAB and its toolboxes which will be used by other modules of this master program. At the same time mathematical knowledge taught in module A1.1 will be complemented. By using MATLAB the student will train some of the key concepts of digital image processing. The foundation developed in this course will be the basis for further studies in this field.
Content	**Introduction to MATLAB** • MATLAB desktop environment • Scalar variables and assignment statements • Arrays (vectors, matrices), array indexing, operations with arrays • Data structures • MATLAB scripts • saving and loading data, importing and exporting data • selection statements, loop statements • debugging techniques • advanced topics: plotting techniques, basic statistics, curve fitting, numerical analysis, symbolic math **Introduction into mathematical concepts and numerical methods** • Matrices o Definitions o Matrix operations o Determinants • Numerical analysis o Interpolation and extrapolation o Numerical integration of functions o Numerical evaluation of functions • Fourier transformation o Fourier series, Fourier integrals o Laplace transforms o The discrete Fourier transform o The fast Fourier transform o Applications: the impulse response, the transfer function **Introduction to image processing** • Analog and digital image acquisition • Mathematics of image formation • Image formats: colour spaces, image data types, image compression, handling images in MATLAB • Image enhancement in the spatial domain: basic gray level transformations, histogram processing, neighborhood processing / spatial filtering • Image enhancement in the frequency domain: Introduction to the Fourier transformation, filtering in the frequency domain • Image restoration: noise models, image degradation models, inverse filtering, geometric distortions, image registration • Morphological image processing: basic concepts, dilation and erosion, opening and closing, filling holes • Image segmentation: detection of discontinuities, thresholding, region-based segmentation, watershed segmentation
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	The module is mandatory for all students.
Usability	The module is part of the “Fundamentals” module in the Medical Photonics program. Skills taught in this module are a prerequisite for other modules such as Image processing II.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h total work load: 120 h

Module number	MedPho - F 1.1
Language	English
Prerequisites	none
Exam prerequisites	regular participation at lectures and exercises
Requirements to complete this module	written or oral examination
Used media	lectures: blackboard, projector exercise: image processing with MATLAB at workstations of the computer pool
Literature	• R.C. Gonzales, R.E. Woods: Digital image processing. 5th ed., Pearson Education 2008. • R.C. Gonzales, R.E. Woods, S.L. Eddins: Digital image processing using MATLAB. Pearson Education 2004. • C. Solomon, T. Breckon: Fundamentals of digital image processing. Wiley-Blackwell 2001.

3.3. Module F 1.2: Biomedical Imaging I (1st semester)

Module number	MedPho - F 1.2
Module name	Biomedical Imaging I – Ionizing Radiation
Coordinator	**Jürgen R. REICHENBACH**
Learning objectives	The course introduces the physical principles, properties and technical concepts of imaging systems as they are applied today in medicine and physics. The focus is laid on the use and application of ionizing radiation. Applications and current developments will be presented. Following active participation the students should demonstrate a critical understanding of the theoretical basis and technologies of these imaging systems and have acquired an appreciation of instrumentation and practical issues with different imaging systems. The course is independent of the course "Biomedical imaging II – Non-Ionizing Radiation" offered in the 2nd semester.
Content	• Introduction to biomedical and medical imaging systems • Physical principles behind the design of selected imaging systems • Technological aspects of each modality • Spatial and temporal resolution • Importance of each modality concerning physical, biological and clinical applications • Interaction of ionizing radiation with biomolecules and cells
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	The module is mandatory for all students.
Usability	The module is part of the "Fundamentals" module in the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self-study: 75 h (lectures, exercises: 45 h, solving of physical problems: 15 h, exam preparation: 15 h) total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this module	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. 2nd ed., Publicis 2006. • P. Suetens: Fundamentals of medical imaging. 2nd ed., Cambridge University Press 2009. • W.R. Hendee, E.R. Ritenour: Medical Imaging Physics. 4th ed., Wiley-Liss 2002. • M.A. Flower: Webb's physics of medical imaging. CRC Press, Taylor & Francis 2012. • J.T. Bushberg, J.A. Seibert, E.M. Leidholdt Jr., J.M. Boone: Essential physics of medical imaging. 3rd ed., Lippincott Raven 2011. • S. Forshier: Essentials of radiation biology and protection. 2nd ed. Cengage Learning 2008.

3.4. Module F 2.1: Image processing II (2nd semester)

Module nuber	MedPho - F 2.1
Module name	Image Processing II – Image processing in microscopy
Coordinator, lecturers	**N.N. (Carl Zeiss professor)**, Rainer HEINTZMANN, Christoph BISKUP,
Learning objectives	Current microscopy techniques often acquire a large amount of image data, based on which the researcher needs to answer very specific questions. This course focusses on algorithms used to extract information from microscopic images. A major topic is the reconstruction of the sample from the acquired, often complex microscopy data. To solve such inverse problems, a good model of the data acquisition process is required, ranging from assumptions about the sample, assumptions about the imaging process (e.g. the existence of an incoherent spatially invariant point spread function) to modeling the noise characteristics of the detection process (e.g. photon shot noise and read noise). All the image processing algorithms and simulations will be practiced in exercises using MATLAB and the free image processing toolbox "DIPImage" (www.diplib.org). At the same time mathematical knowledge taught in module A1.1 will be complemented.
Content	**Introduction into advanced topics of image processing with focus on microscopic image processing** • Image acquisition on the stage of a microscope • Toolboxes for processing of microscopic images: ImageJ, MATLAB, DIPImage • Mathematics of microscopic image formation: point spread function, convolution • Deconvolution: reconstruction of 3-dimensional images • Denoising: noise models, filtering of microscopic images • Segmentation of microscopic images • Image registration: correction of geometric distortions, artefacts caused by moving objects • Evaluation of multidimensional data: time-series, spectrally resolved measurements, fluorescence lifetime measurements **Introduction into mathematical concepts** • Sampling theory • Fitting models to data o Linear regression, Non-linear regression o Weighting of data points o Interpreting the results: confidence intervals of the parameters, comparing models o Optimizing the results: constraining the fit • Other topics based on the student's needs
Course type	lectures: 2h/week exercise: 1h/week
ECTS credits	4
Category	The module is mandatory for all students.
Usability	The module is part of the "Fundamentals" block in the Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h total work load: 120 h
Language	English
Prerequisites	The student needs to have completed the course "Mathematical Methods" (Module A 1.1) and "Image Processing I" (Module F 1.1). He/she should be familiar with MATLAB and basic concepts of image processing taught in the module F1.1.
Exam prerequisites	regular participation at lectures and exercises
Requirements to complete this module	written or oral examination
Used media	lectures: blackboard, projector exercises: image processing with MATLAB at workstations of the computer pool

Module nuber	MedPho - F 2.1
Literature	• R.C. Gonzales, R.E. Woods: Digital image processing. Pearson Education 2008. • R.C. Gonzales, R.E. Woods, S.L. Eddins: Digital image processing using MATLAB. Pearson Education 2004. • C. Solomon, T. Breckon: Fundamentals of digital image processing. Wiley-Blackwell 2001. • List of publications provided at the beginning of the course.

3.5. Module F 2.2: Biomedical Statistics (2nd semester)

Module number	MedPho - F 2.2
Module name	Biomedical Statistics
Coordinator, lecturers	**Lutz LEISTRITZ**, Katrin SCHIECKE
Learning objectives	The students learn basic principles of mathematical statistics and are familiarized with statistical thinking. The students will be enabled to apply statistical methods to biomedical data.
Content	The lecture course imparts basics, fundamental terms, and conditions of biomedical data analysis. The following subjects are concerned: fundamentals of the theory of probabilities, fundamental terms of epidemiology, descriptive statistics, diagnostic tests, random variables, particular probability distributions, estimations, statistical tests, multiple testing, bootstrapping, correlation, regression, design and execution of experiments. Exercises are given in groups of ten to twenty students by involving the statistical software SPSS. This group size enables each student to use an own workstation during the course.
Course type	lectures: 2h/week exercises: 2h/week
ECTS credits	4
Category	The module is mandatory for all students.
Usability	The module is part of the “Fundamentals” module in the Medical Photonics program. Skills taught in this module are a prerequisite for other modules.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 30 h self study: 60 h total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in exercises
Requirements to complete this module	written examination
Used media	lectures: blackboard, projector exercises: seminars and practical SPSS courses at computers of the computer pool
Literature	References will be given at the beginning of the course.

4. Block Specialization

4.1. Block S: Specialization (2nd and 3rd semester)

Block number	MedPho – S
Block name	Specialization
Coordinators	Christoph BISKUP, N.N.
Learning objectives	The specialization block allows the student to choose 2 modules in the 2nd semester and 3 modules in the 3rd semester according to his/her focus of interest.
Content	Courses of the 2nd semester provide an introduction the following techniques: • Biomedical Imaging II (non-ionizing radiation) (module S2.1) • Microscopy (Module S2.2) • Labelling techniques (Module S2.3) • Lasers (Module S2.4) • Fiber optics (Module S2.5) 2 out of the 9 modules offered need to be chosen. In the 3rd semester the student can specialize in the following fields: • Microscopy (Modules S3.1-S3.4) • Clinical Applications (Modules S3.5-S3.8) • Spectroscopic Applications (Modules S3.9-S3.12) 3 out of the 12 modules offered need to be chosen; at least two of the research fields should be covered.
Course type	Lectures and exercises organized as 5 individual modules in 2 semesters
ECTS credits	8 ECTS credits in the 1st semester, 12 ECTS credits in the 2nd semester, 20 ECTS credits in total
Category	The student has to choose 2 modules in the 2nd semester and 3 modules in the 3rd semester according to his/her focus of interest.
Usability	block of the 2nd and 3rd semester.
Frequency of offer	summer semester (1st part) + winter semester (2nd part)
Duration	2 semester
Work load	lectures: 150 h exercises: 75 h self study: 375 h total work load: 600 h
Language	English
Prerequisites	specifically defined in the description of the individual modules
Exam prerequisites	specifically defined in the description of the individual modules
Requirements to complete this module	The successful completion of 2 modules in the 2nd semester and of 3 modules in the 3rd semester (5 modules in total) is required.
Used media	specifically defined in the description of the individual modules
Literature	specifically defined in the description of the individual modules

4.2. Module S 2.1: Advanced Mathematics (2nd semester)

Module number	MedPho - S 2.1
Module name	Advanced Mathematics
Coordinator, lecturers	Agnes SAMBALE
Learning objectives	This course continues the training in mathematical concepts and methods given in module A1.1. The intention of this course is to give the students a broader background in mathematics so that they can cope successfully with the mathematics required to treat advanced problems in optics or physical chemistry.

Content	• Differential equations (Cont.)
	  o Laplace Transforms
	• Multiple integrals
	  o Methods of integration
	• Vector analysis
	  o Line, surface and volume integrals
	  o Flow of a vector field through a surface element
	  o Computing surface and volume integrals

Course type	lectures: 2h/week exercises: 2h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 2nd semester according to the student's education objectives.
Usability	The module is part of the “Specialization” block in the Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 30 h self study: 60 h total work load: 120 h
Language	German / English
Prerequisites	solid background in mathematics, successful completion of the module “Mathematical methods” (module A1.1)
Exam prerequisites	regular participation at lectures and exercises, students must have earned in the exercises more than 50% of the available points
Requirements to complete this module	written examination
Used media	lectures: blackboard, projector exercise: pen, paper
Literature	• Script given at the beginning of the lecture • M.L. Boas: Mathematical Methods in the Physical Sciences. 3rd ed., John Wiley 2005. • K.F. Riley, M.P. Hobson: Essential Mathematical Methods for the Physical Sciences. Cambridge University Press 2011. • H. Schulz: Physik mit Bleistift: das analytische Handwerkszeug der Naturwissenschaftler. • G.F. Simons: Calculus with Analytic Geometry, McGraw Hill 1996. • K. Weltner, S. John, W.J. Weber, P. Schuster, J. Grosjean: Mathematics for Physicists and Engineers. 2nd ed., Springer 2014

4.3. Module S 2.2: Biomedical Imaging II (2nd semester)

Module number	MedPho - S 2.2
Module name	Biomedical Imaging II – Non-Ionizing Radiation
Coordinator	**Jürgen R. REICHENBACH**
Learning objectives	The course introduces physical principles, properties and technical concepts of imaging systems as they are applied today in medicine and physics. The focus is laid on the use and application of non-ionizing radiation, as utilized, e.g., with magnetic resonance imaging or ultrasound imaging. Applications and current developments will be presented. Following active participation the students should demonstrate a critical understanding of the theoretical basis and technologies of these imaging systems and have acquired an appreciation of instrumentation and practical issues with different imaging systems. The course is independent of the course "Biomedical imaging I – Ionizing Radiation" offered in the 1st semester.
Content	• Introduction to imaging systems • Physical principles behind the design of selected biomedical imaging systems, including magnetic resonance imaging, ultrasound imaging • Technological aspects of each modality • Importance of each modality concerning physical, biological and clinical applications
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 2nd semester according to the student's education objectives.
Usability	This module is part of the block "Specialization" in the 2nd semester of the Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	Lectures and lab tours: 30 h exercises: 15 h self-study: 75 h (lectures, exercises: 45 h, solving of physical problems: 15 h, exam preparation : 15 h) total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	regular participation in lectures and exercises
Requirements to complete this module	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. 2nd ed., Publicis 2006. • P. Suetens: Fundamentals of medical imaging. 2nd ed., Cambridge University Press 2009. • W.R. Hendee, E.R. Ritenour: Medical Imaging Physics. 4th ed., Wiley-Liss 2002. • M.A. Flower: Webb's physics of medical imaging. CRC Press, Taylor & Francis 2012. • J.T. Bushberg, J.A. Seibert, E.M. Leidholdt Jr., J.M. Boone: Essential physics of medical imaging. 3rd ed., Lippincott Raven 2011

4.4. Module S 2.3: Microscopy (2nd semester)

Module number	MedPho - S 2.3
Module name	Microscopy
Coordinator, lecturers	**Herbert GROSS**, Michael KEMPE, N.N. (Carl Zeiss professor), Rainer HEINTZMANN, Martin WESTERMANN, Klaus JANDT
Learning objectives	This module provides an introduction into the fundamentals of modern light and electron microscopy.
	• Optical microscopy (GROSS, HEINTZMANN, N.N.) o Components of a light microscope o Image formation in a light microscope o Köhler and critical illumination o Diffraction and interference in image formation, spatial resolution o Impact of aberrations on the functionality o Volume imaging, 3D transfer function theory o Generating contrast: dark field contrast, phase contrast, differential interference contrast o Polarization microscopy o Fluorescence microscopy, confocal laser scanning microscopy, two-photon excitation microscopy o Effects of coherence and scattering, OCT-principle o Deconvolution approaches in 2 and 3-dimensions • Circumventing the resolution limit (Introduction) (GROSS, HEINTZMANN, N.N.) o 4Pi-microscopy o Structured illumination (SIM) microscopy o Single-molecule localization microscopy o Stimulated emission depletion (STED) microscopy • Introduction into electron microscopic techniques (WESTERMANN) o Transmission electron microscopy (TEM) o Scanning electron microscopy (SEM) o Electron microprobe analysis o Correlative light and electron microscopy • Introduction into atomic force microscopy (JANDT) o Working modes, tip-sample interactions, scanners, probes o Sample preparation o other scanning probe methods: scanning near field optical microscopy (SNOM)
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 2nd semester according to the student's education objectives.
Usability	This module is part of the block „Specialization“ of the 2nd semester.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 60 h, exam preparation: 15 h) total work load: 120 h
Language	English
Prerequisites	Fundamental knowledge in optics taught in modules A1.2 and A 2.2.
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	Lectures/excercises: blackboard, projector
Literature	• Textbooks on optics: o E. Hecht: Optics, 4th ed., Addison-Wesley 2001 • Microscopy textbooks/handbooks o D.B. Murphy, M.W. Davidson: Fundamentals of light microscopy and electronic imaging. 2nd ed., Wiley Blackwell 2013. o R.F. Egerton: Physical principles of electron microscopy. Springer 2005 o P. Eaton, P. West: Atomic force microscopy. Oxford University Press 2010

4.5. Module S 2.4: Dyes and Labels (2nd semester)

Module number	MedPho - S 2.4
Module name	Dyes and Labels
Cordinator, lecturers	**Kalina Peneva**, Christoph BISKUP
Learning objectives	The purpose of staining in microscopy is to label microscopic structures and to add contrast to the specimen. This course introduces the student to staining techniques, the chemical nature of dyes and fluorescent labels.
Content	• Introduction to pigments, dyes and fluorochromes o Definition, physical and chemical properties of pigments, dyes and fluorochromes o Nomenclature and classification of pigments, dyes and fluorochromes o Dye purity and dye standardization • Biomedical applications o Overview of applications o Mechanism of biological staining • Reactive staining reagents and fluorescent labels o Principles and strategies o Bonding mechanisms to biological materials: functional targets, chemistry of reactive groups • Indicators o Measurement principles of pH-, ion, redox and potential sensitive indicators o Pitfalls o Ratiometric measurements o Nanosensors • Bioconjugate techniques
Course type	lectures: 2h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 2nd semester according to the student's education objectives.
Usability	This module is part of the block “Specialization” in the 2nd semester of the Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	Lectures: 30 h self-study: 90 h (lectures: 60 h, exam preparation : 30 h) total work load: 120h
Language	German / English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination
Used media	blackboard, projector, specimens & dyes for the practical part of the course
Literature	• H. Zollinger: Color chemistry: Syntheses, properties, and applications of organic dyes and pigments. 3rd ed. Helvetica Chimica Acta 2003. • R.W. Horobin, J.A.Kiernan: Conn’s biological stains. 10th ed. Taylor & Francis 2002. • G.T. Hermanson: Bioconjucate techniques. 2nd ed. Academic Press 2008. • list of publications given during the lecture

4.6. Module S 2.5: Lasers in Medicine (2nd semester)

Module number	MedPho - S 2.5
Module name	Lasers in Medicine
Coordinator	N.N. (PAF)
Learning objectives	The students will be introduced to the basic mechanisms of laser-tissue interactions. Different laser technologies will be presented. Their application in different fields of clinical medicine and diagnostics will be discussed.
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	This module can be elected out of the list of offered modules in the 2nd semester according to the student's education objectives.
Usability	This module is part of the module “Specialization” in the 2nd semester of the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 45 h, studying and discussing recent publications: 30h) total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written or oral examination, depending on the number of students participating in the course
Used media	lectures: blackboard, projector excercises: pdfs of publications
Literature	• A.J. Welch, M.J.C. van Gemert: Optical-thermal response of laser irradiated tissue. 2nd ed. Springer 2011 • M.H. Niemz: Laser-tissue interactions: Fundamentals and applications. 3rd ed., Springer 2003. • H.P. Berlien, H. Breuer, G.J. Müller, N. Krasner, T. Okunata, D. Sliney: ”Applied Laser Medicine” Springer 2003. • list of publications given during the lecture

4.7. Module S 2.6: Fiber optics (2nd semester)

Module number	MedPho – S 2.6
Module name	Fiber Optics
Coordinator, lecturers	**Markus A. SCHMIDT**
Learning objectives	This course introduces to the making and properties of different types of optical fiber waveguides. Applications of optical fibers to optical communication, optical sensing and medicine will be discussed. This course is held within the framework of the Abbe School of Photonics.
Content	• Properties of optical fibers • Light propagation in optical fibers • Fiber based waveguide optics • Special fiber types (micro structured optical fibers) • Fiber amplifiers and fiber lasers • Optical communication with fibers • Optical sensing with fibers
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of a list of offered modules according to the students education objectives
Usability	This module is part of the block "Specialization" in the 2nd semester of the Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 45 h, exam preparation: 30h) total work load: 120 h
Language	English
Prerequisites	Fundamental knowledge in optics taught in the module A 2.2
Exam prerequisites	none
Requirements to complete this module	written or oral examination at the end of the semester (as announced in the lecture)
Used media	blackboard, beamer, overhead projector, written supplementary material
Literature	• Textbooks on optics: o B.E.A. Saleh, M.C. Teich: Fundamentals of photonics 2nd ed., Wiley 2007. • Textbooks on optical fibers: o M.L. Calvo, V. Lakshminarayanan: Optical waveguides: From theory to applied technologies. St Lucie Press 2007. o K. Okamoto: Fundamentals of optical waveguides. 2nd ed. Academic Press 2006. • List of selected journal publications given during the lecture

4.8. Module S 2.7: Image Understanding (2nd semester)

Module number	MedPho – S 2.7
Module name	Image Understanding
Coordinator	**Joachim DENZLER**
Learning objectives	This course introduces to methods capable of understanding the content of an image or a sequence of images. In contrast to general techniques for preprocessing images (Module F1.1-Image Processing I) or for specific image enhancement and correction in case of microscopy images (Module F2.1-Image Processing II), this module covers methods to extract high-level information from images that can be the basis for decisions made by a human or a machine (Module S2.8-Visual recognition and analysis). The main focus is on advanced segmentation techniques to separate the image into parts that represent objects or events of interest, and on specific object detection techniques.
Content	• **Introduction to Image Understanding** o General Processing Pipeline in Image Understanding o Applications • **Basic Image Segmentation Techniques** o Local Features (Corners, Blobs, SIFT and SURF Feature, Salience Measures) o Bag of Features o Region Segmentation • **Advanced Segmentation Techniques** o Segmentation by Classification o Segmentation as Operations on Graphs o Active Contours, Level-Set Methods • **Object Detection by Shape and Appearance** o Simple Shape Models (Template Matching, Hough Transform) o Active Shape Models and Active Appearance Models o Learned Object Detectors • **Image Sequence Processing** o Motion Computation o Template Based Object Tracking • **Object Tracking by Detection**
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of a list of offered modules according to the students education objectives
Usability	This module is part of the block “Specialization” in the 2nd semester of Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h total work load: 120 h
Language	English
Prerequisites	Fundamental knowledge in mathematics taught in the modules A 0.1 and A1.1. MATLAB programming skills taught in module F1.1.
Exam prerequisites	regular participation at lectures and exercises
Requirements to complete this module	written or oral examination at the end of the semester (as announced in the lecture)
Used media	lectures: blackboard, projector exercise: image processing with MATLAB at workstations of the computer pool
Literature	• Klaus Toennies: Guide to Medical Image Analysis. Springer 2012

4.9. Module S 2.8: Visual Recognition and Analysis (2nd semester)

Module number	MedPho – S 2.8
Module name	Visual Recognition and Analysis
Coordinator	**Erik RODNER**
Learning objectives	This course introduces to advanced visual recognition techniques, which are important to analyze image and sensor data automatically. Students will learn about the challenges in the area and about various techniques that can be used to localize and analyze structures and objects of interest in visual data.
Content	• Brief summary of basic machine learning techniques (nearest neighbour, SVM) • Local and high-level global descriptors (histograms of gradient orientations, dictionary learning, sparse coding) • Image categorization with supervised and unsupervised methods (large-scale learning, efficient global features, clustering) • Localization with sliding window methods (Haar-like features, boosting, random forests, feature maps and convolution) • Semantic segmentation (convolutional neural networks, available toolboxes, exercises based on medical data and counting tasks)
Course type	lectures: 1h/week exercises: 2h/week
ECTS credits	4
Category	This module can be elected out of a list of offered modules according to the students education objectives
Usability	This module is part of the block “Specialization” in the 2nd semester of the Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 15 h exercises: 30 h self study: 75 h total work load: 120 h
Language	English
Prerequisites	Fundamental knowledge in mathematics taught in the modules A 0.1 and A1.1. MATLAB programming skills taught in module F1.1.
Exam prerequisites	none
Requirements to complete this module	written or oral examination at the end of the semester (as announced in the lecture)
Used media	lectures: blackboard, projector exercises: visual recognition with MATLAB
Literature	• H. Süße, E. Rodner: Bildverarbeitung und Objekterkennung, Springer-Vieweg 2014 • R. Szeliski: Computer Vision: Algorithms and Applications, Springer 2011 (free online version available) • list of publications given in the lectures

4.10. Module S 2.9: Management of Scientific Data (2nd semester)

Module number	MedPho – S 2.9
Module name	Management of Scientific Data
Coordinator	**Birgitta KÖNIG-RIES**
Learning objectives	Learning objectives of this module are to introduce students to the stages of the data life cycle in various disciplines. They will gain experience with typical tools supporting the individual steps and be able to plan and perform data management for scientific projects.
Content	The course follows the data lifecycle and explores challenges, solutions and open problems of the individual steps, including: • overview of the data lifecycle: data collection, quality assurance, data storage and preservation, data analysis and visualization, data publication, data discovery, data reuse and hypothesis generation • cross-cutting topics covered include: Metadata standards and ontologies, scientific workflow management, persistent identifiers for data, data provenance and versioning.
Course type	lectures: 2h/week exercises: 2h/week
ECTS credits	4
Category	This module can be elected out of a list of offered modules according to the students education objectives
Usability	This module is part of the block “Specialization” in the 2na semester of the Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 30 h self study: 60 h total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	regular and active participation at exercises, students must have earned in the exercises more than 50% of the available points
Requirements to complete this module	written or oral examination at the end of the semester (as announced at the beginning of the course)
Used media	lectures: blackboard, projector exercises: workstations of the computer pool
Literature	• list of publications given in the lectures and exercises

4.11. Module S 3.1: Biological Microscopy (3rd semester)

Module number	MedPho - S 3.1
Module name	Biological Microscopy
Coordinator	**Christoph BISKUP**, Klaus BENNDORF, Knut HOLTHOFF, Knut KIRMSE, Ralf MROWKA, Eva NEUHAUS, Ralf SCHMAUDER, Stefan SCHULZ, Ralf STUMM
Learning objectives	
Content	• Biological model systems • Microscopy of living cells • Specimen preparation • Fluorophores for biological imaging o Biological stains o Fluorescent labels, labelling strategies o Fluorescent indicators o Fluorescent analogues of biomolecules o Genetically expressed intracellular indicators o Photophysical problems, signal optimization • Manipulation of cells and tissues with optical tools o Caged compounds o Photochromic switches o Optogenetics • Applications in physiological and pharmacological research o Measuring Ca^{2+} transients o Real-time imaging of cAMP signaling of endogenous GPCRs o High-resolution microscopy of signalling proteins in olfactory cilia o Life imaging of neuronal migration o Confocal patch clamp fluorometry
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block “Specialization” in the 3rd semester of the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written or oral examination, depending on the number of students participating in the course
Used media	lectures: blackboard, projector exercise: study
Literature	• Textbooks and handbooks o J.B. Pawley: Handbook of biological confocal microscopy. 3rd ed. Springer 2006. • List of publications provided at the beginning of the course.

4.12. Module S 3.2: Single-Molecule Microscopy (3rd semester)

Module number	MedPho - S 3.2
Module name	Single-Molecule Microscopy
Coordinator	**Michael BÖRSCH**, Ralf SCHMAUDER
Learning objectives	In conventional microscopy experiments fluorescence data are acquired from a large number of molecules. Since many molecules are interrogated simultaneously, their properties are averaged out. In contrast to this single-molecule experiments provide access to an incredible wealth of information. This course gives an introduction to single-molecule techniques and the analysis of the data.
Content	• Single-molecule imaging • Fluorophore labelling for single-molecule fluorescence microscopy • Single-molecule tracking • Single-molecule FRET • Single-molecule studies of molecular rotors • Fluorescence correlation spectroscopy
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block “Specialization” in the 3rd semester of the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h total work load: 120 h
Language	English
Prerequisites	Fundamental knowledge in microscopy taught in module S 2.3
Exam prerequisites	none
Requirements to complete this module	oral examination
Used media	lectures: blackboard, projector exercise: image processing with MATLAB at workstations of the computer pool
Literature	• List of publications provided at the beginning of the course.

4.13. Module S 3.3: Electron Microscopy (3rd semester)

Module number	MedPho - S 3.3
Module name	Electron Microscopy
Coordinator	**Martin WESTERMANN**, Sandor NIETSCHE, Klaus JANDT, Stephanie HÖPPENER, Ulrich Sigmar SCHUBERT
Learning objectives	This module provides an introduction into the fundamentals of electron microscopy.
Content	• History • Principles & theories • Instrumentation o Transmission electron microscopy (TEM) o Scanning electron microscopy (SEM) o Electron microprobe analysis o Correlative light and electron microscopy • Electron microscopy of biological samples o Processing of tissue specimens: Fixation – Washing and dehydration – Infiltration and embedding – sectioning – staining o Processing of cell cultures o Cryotechniques, freeze fracture electron microscopy o Immunelectron microscopy o Artifacts in electron microscopy • Electron microscopy of biomaterials • Electron microscopy of polymers
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block “Specialization” in the 3rd semester of the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 60 h, exam preparation: 15 h) total work load: 120 h
Language	English
Prerequisites	Fundamental knowledge in microscopy taught in module S 2.3.
Exam prerequisites	None
Requirements to complete this module	written examination at the end of the semester
Used media	Lectures/excercises: blackboard, projector
Literature	• Textbooks and handbooks o D.B. Murphy, M.W. Davidson: Fundamentals of light microscopy and electronic imaging. 2nd ed., Wiley Blackwell 2013. o R.F. Egerton: Physical principles of electron microscopy. Springer 2005

4.14. Module S 3.4: Nanooptics (3rd semester)

Module number	MedPho - S 3.4
Module name	Nanooptics
Coordinator	**Thomas PERTSCH**
Learning objectives	The course provides an introduction to the fundamentals of the broad research field of nanooptics. 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	To reach this objective the course will cover a basic introduction to the following topics: • Propagating modes and localized modes • Mie-scattering • Surface-plasmon-polaritons • Plasmonics • Photonic crystals • Photonic nanomaterials • Basics of nanotechnologies for the realization of optical nano-structures • Techniques for the experimental characterization of optical nano-structures
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block “Specialization” in the 3rd semester of the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 60 h, exam preparation: 15 h) total work load: 120 h
Language	English
Prerequisites	fundamental knowledge in modern optics, basics of condensed matter physics and electrodynamics, basics of vector analysis
Exam prerequisites	None
Requirements to complete this module	written examination at the end of the semester and oral presentation on a current research topic
Used media	Lectures/excercises: blackboard, electronic presentations, laboratory teaching
Literature	• lecture script • list of selected journal publications given during the lecture • Textbooks and handbooks o L. Novotny, B. Hecht: Principles of Nano-Optics, Cambridge 2006. o P. Prasad: Nanophotonics, Wiley 2004.

4.15. Module S 3.5: Principles in Ophthalmology (3rd semester)

Module number	MedPho - S 3.5
Module name	Principles in Ophthalmology
Coordinator	**N.N. (Med)**, Martin HAMMER, N.N. (PAF)
Learning objectives	After revising the anatomy and physiology of the eye, which is introduced in module A2.3, this course will discuss the pathophysiology and treatment of diseases of the eye. Emphasis will be laid on optical instruments and optical methods used for diagnosis and treatment.
Content	• Anatomy and physiology of the eye o optical properties of the eye, image formation in the eye o photoreception in the retina o signal processing in the retina o central visual pathways • Ophthalmic instrumentation • Clinical ophthalmology o Cornea and ocular surface diseases: pathophysiology, corneal surgery o Refraction errors: testing of refraction, lenses, refractive surgery o Cataract: pathophysiology, cataract surgery o Glaucoma: diagnosis, treatment, laser therapy used in the treatment of glaucoma o Retina: ▪ pathophysiology of diseases of the retina: • vascular disorders: arterial obstruction, ischemia, hypertensive retinopathy, diabetic retinopathy • macular disorders: age-related macular degeneration, optic nerve and macular abnormalities • retinal detachment ▪ diagnostic procedures: • angiography • optical coherence tomography • fluorescence lifetime imaging ▪ principles of retinal surgery
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block “Specialization” in the 3rd semester of the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 45 h, studying and discussing recent publications, solving problems: 30h) total work load: 120 h
Language	English
Prerequisites	knowledge taught in modules Human Biology (A1.4 + A2.3), Optical Engineering (A1.2) and Physical Optics (A2.1) or equivalent modules
Exam prerequisites	none
Requirements to complete this module	written or oral examination, depending on the number of students participating in the course
Used media	lectures: blackboard, projector excercises: pdfs of publications
Literature	• Textbooks of physiology (see description for the modules Human Biology I + II) • M. Yanoff, J.S. Duker, .J. Augsburger: Ophthalmology, 3rd ed., Mosby 2008. • G. Smith, D.A. Atchison: The eye and visual optical instruments. Cambridge University Press 1997. • list of publications given during the lecture

4.16. Module S 3.6: Medical diagnosis and therapy (3rd semester)

Module number	MedPho - S 3.6
Module name	Optical techniques in medical diagnosis and therapy
Coordinator, lecturers	**Orlando GUNTINAS-LICHIUS**, Andreas STALLMACH, Martin KAATZ
Learning objectives	The students will be introduced into optical techniques used in medical diagnostics and therapy.
Content	• Biophotonic techniques for structural and functional imaging in vivo o Microscopes o Endoscopes (principles, designs, accessoires, applications) o Confocal laser scanning endomicroscopy o Light sources o Laser technology o Procedures for cleaning, sterilizing and storing of the equipment • Applications in dermatology o Anatomy and physiology of the skin o Pigments and autofluorophores of the skin o Tumor classification with optical methods o Diagnosis of inflammation o Changes associated with ageing • Applications in otorhinolaryngology o Histology and anatomy of the nose, paranasal sinuses, oral cavity, pharynx and larynx o Endoscopy o Laser surgery • Applications in gastroenterology o Microarchitecture of the normal gut seen with conventional histology, conventional endoscopes and endomicroscopes o Endoscopy and in vivo fluorescence endomicroscopy of disorders of the gastrointestinal tract o Functional and molecular imaging o Photodynamic therapy
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block “Specialization” in the 3rd semester of the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 45 h, studying and discussing recent publications, solving problems: 30h) total work load: 120 h
Language	English
Prerequisites	knowledge taught in modules Human Biology (A1.4 + A2.3) and Optical Engineering (A1.2) or equivalent modules
Exam prerequisites	none
Requirements to complete this module	written or oral examination, depending on the number of students participating in the course
Used media	lectures: blackboard, projector excercises: pdfs of publications
Literature	• R. Kiesslich, P.R. Galle, M.F. Neurath: Atlas of endomicroscopy. Springer 2008 • list of publications given during the lecture

4.17. Module S 3.7: Theranostics (3rd semester)

Module number	MedPho – S 3.7
Module name	Theranostics
Coordinator, lecturers	**Dagmar FISCHER**, Ulrich Sigmar SCHUBERT, Michael BAUER
Learning objectives	Essential to an efficient therapy of many diseases is a precise diagnosis and a selective application of potent therapeutic agents. To this aim imaging methods have been improved, and strategies for targeted delivery and localized activation of therapeutic agents have been developped. Theranostic approaches try to combine diagnostic and therapeutic techniques by synthesizing carrier systems capable of specific targeting and carrying imaging and therapeutic agents for accurate diagnosis and controlled release. This course introduces the student into current techniques and therapeutic applications.
Content	• Theranostics: Definition and Introduction • Dyes, fluorophores and nanomaterials for light-based diagnostic applications • Photodynamic therapy, photosensitizers • Photothermal therapy • Theranostic nanocarriers o Design principles of carrier structures o Targeting strategies o Diagnostic and therapeutic agents
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block „Specialization“ of the 3rd semester.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 45 h, exam preparation: 30h) total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	blackboard, beamer, overhead projector, written supplementary material
Literature	• List of selected journal publications given during the lecture

4.18. Module S 3.8: Biomaterials (3rd semester)

Module number	MedPho – S 3.8
Module name	Optical Characterization of Biomaterials
Coordinator	**Klaus JANDT**, Jörg BOSSERT
Learning objectives	Biomaterials are widely used in regenerative medicine and dental medicine, where biological substitutes and scaffolds are created to mimic and replace natural tissues. The main aim of this course is to introduce the student to the field of biomaterials, applications where the optical properties of biomaterials are important and the characterization of biomaterials with optical techniques.
Content	• Fundamentals of Materials Science • Application of biomaterials in clinical medicine o Bone replacement o Dental materials o Biomaterials for ophthalmologic applications o Materials and scaffolds for biomedical engineering o Cell mechanics, cell-cell and cell-matrix interactions o Biomimetics • Optical methods for inspection, characterization and imaging of biomaterials o Light microscopy (LM, CLSM) o Spectroscopy and scattering o X-ray diffraction o Electron microscopy (SEM-FIB, ESEM, TEM) o Atomic force microscopy o X-ray microtomy o 3D-reconstruction o Preparation of samples • Biological reactions to biomaterials
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block „Specialization“ of the 3rd semester.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 45 h, exam preparation: 30h) total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	blackboard, beamer, overhead projector, written supplementary material
Literature	• B.D. Ratner, A.S. Hoffmann, F.J. Schoen, J.E. Lemons: Biomaterials Science. An introduction to materials in medicine. 3rd ed. Academic Press 2012. • List of selected journal publications given during the lecture

4.19. Module S 3.9: Chemometrics (3rd semester)

Module number	MedPho - S 3.9
Module name	Chemometrics
Coordinator	**Thomas BOCKLITZ**, Jürgen POPP
Learning objectives	This module provides an introduction into the fundamentals of statistical data evaluation i.e. general concepts of chemometric approaches to analyse optical molecular microspectroscopic images of biological samples like e.g. cells or tissue.
Content	• Introduction into statistics (univariate, multivariate) • Spectroscopic pre-treatment procedures • Introduction into image analysis (filter methods, property calculation, segmentation approaches, object recognition) • Analysis methods (optimization problems and optimization methods, classification models (possible examples: LDA, SVM, ANN), multivariate calibration methods, evaluation procedures, factor methods (possible examples: PCA, ICA, NMF), cluster algorithms (possible examples: k-means-CA, c-means-CA, HCA, VCA, N-FINDR))
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block “Specialization” in the 3rd semester of the Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 45 h, exam preparation: 30h) total work load: 120 h
Language	English
Prerequisites	Basic knowledge in mathematics and programming taught in modules F1.1 and F2.1
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	blackboard, beamer, overhead projector, written supplementary material
Literature	• K. R. Beebe, R. J. Pell und M. B. Seasholtz, Chemometrics: A Practical Guide, John Wiley & Sons, New York 1998. • T. Hastie, R. Tibshirani und J. Friedman, The Elements of Statistical Learning – Data Mining, Inference, and Prediction, Springer Verlag 2008. • List of selected journal publications given during the lecture

4.20. Module S 3.10: Microspectroscopy (3rd semester)

Module number	MedPho – S 3.10
Module name	Microspectroscopy
Coordinator	**Ute NEUGEBAUER**, Michael SCHMITT, Jürgen POPP
Learning objectives	The aim of this course is to present modern methods in linear and non-linear vibrational microspectroscopy (IR absorption, Raman, resonance Raman, SERS, TERS, CARS, SRS, etc.) dedicated to biological samples. The potential as well as the limitations of these label-free vibrational spectroscopic techniques towards a more reliable medical diagnosis will be discussed.
Content	• Molecular vibrations (normal mode concept) • Infrared absorption spectroscopy / microscopy, vibrational circular dichroism (VCD) for biomedical diagnostics • Raman scattering (classical and quantum mechanical description) • Raman microscopy for biomedical diagnostics • Raman signal enhancing approaches (resonance Raman, surface enhanced Raman scattering SERS) and its application for biomedical analysis • Tip-enhanced Raman scattering TERS • Introduction into non-linear Raman approaches (Hyper-Raman, coherent anti-Stokes Raman scattering CARS, stimulated Raman scattering SRS) • Non-linear Raman microscopy (CARS- and SRS microscopy) for biomedical diagnostics • Other labelfree non-linear microspectroscopic approaches (two-photon excited autofluorescence TPEF, second harmonic generation) • Non-linear multimodal imaging for labelfree biomedical diagnostics
Course type	lectures: 3h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block “Specialization” in the 3rd semester of the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 45 h self study: 75 h (lectures: 45 h, exam preparation: 30h) total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	blackboard, beamer, overhead projector, written supplementary material
Literature	• J. Popp, V.V. Tuchin, A. Choi, S.H. Heinemann (Eds): Handbook of Biophotonics, Volume 1: Basics and Techniques, Wiley, 2011. • B. Schrader (Ed.): Infrared and Raman Spectroscopy: Methods and Applications, VCH Weinheim 1995. • List of selected journal publications given during the lecture.

4.21. Module S 3.11: Mass Spectrometry Imaging (3rd semester)

Module number	MedPho – S 3.11
Module name	Mass Spectrometry Imaging
Coordinator	**Ferdinand VON EGGELING**, Ulrich Sigmar SCHUBERT
Learning objectives	The aim of this course is to present modern methods of Mass Spectrometry Imaging (MSI) for the analysis of complex tissue sections. These techniques like MALDI (Matric assisted laser desorption and ionization) Imaging or Desorption ionization electrospray imaging (DESI) are especially used for the analysis of tumor tissues. The potential as well as the limitations of these label-free spectrometric techniques towards a more differentiated medical diagnosis will be discussed.
Content	• Mass spectrometers, types and technical principles • MALDI Imaging technical aspects • MALDI Imaging for the analysis of organs and complex tissue • Image analysis by different software (PCA, Segmentation maps etc.) • Identification of biomarker • DESI technical aspects • DESI analysis of tissues ex vivo • Correlation to other imaging techniques (Raman, MRI etc.)
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block “Specialization” in the 3rd semester of the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 45 h, exam preparation: 30h) total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	blackboard, beamer, overhead projector, written supplementary material
Literature	• Norris JL, Caprioli RM. Analysis of tissue specimens by matrix-assisted laser desorption/ionization imaging mass spectrometry in biological and clinical research. Chem. Rev. 113, 2309-42 (2013). • list of references given during the course

4.22. Module S 3.12: Optical Sensors, Microfluidics (3rd semester)

Module number	MedPho – S 3.12
Module name	Optical Sensors, Microfluidics
Coordinator	**Wolfgang FRITZSCHE**, Thomas HENKEL
Learning objectives	This course introduces miniaturized approaches to bioanalytics with a special focus on parallel (microarrays) and nanoscale (nanosensors) methods, complemented by a review of microfludics and its applications. It will give an overview over the basic techniques in this field, list first applications and discuss emerging future trends.
Content	• Biosensors: Definition and Introduction • Marker-based and label-free approaches • Parallel bioanalytics (microarray, DNA chip) • Detection schemes for chip-based analytics • Microfluidics for bioanalytics/diagnostics • POC-systems • Nanosensors in bioanalytics/diagnostics • Optical approaches for nanosensor readout
Course type	lectures: 2h/week exercises: 1h/week
ECTS credits	4
Category	This module can be elected out of the list of offered modules in the 3rd semester according to the student's education objectives.
Usability	This module is part of the block „Specialization“ of the 3rd semester.
Frequency of offer	winter semester
Duration	1 semester
Work load	lectures: 30 h exercises: 15 h self study: 75 h (lectures + exercises: 45 h, exam preparation: 30h) total work load: 120 h
Language	English
Prerequisites	none
Exam prerequisites	none
Requirements to complete this module	written examination at the end of the semester
Used media	blackboard, beamer, overhead projector, written supplementary material
Literature	• R. Marks, C.R. Lowe, D.C. Cullen, H.H.Weetall: Handbook of Biosensors and Biochips, Wiley 2007 • W. Fritzsche, M. Lamy de la Chapelle: Molecular Plasmonics, Wiley 2014 • List of selected journal publications given during the lecture

5. Practical courses / Research Labwork

5.1. Module P 1: Practical Course (1st and 2nd semester)

Module number	MedPho – P 1
Module name	Practical Course
Coordinators	• Optics: N.N. (PAF) • Physical chemistry: Jürgen POPP, Michael SCHMITT • Physiology: Christoph BISKUP
Learning objectives	The course provides an introduction to experimental techniques in optics, physical chemistry and medicine. The students gain experience in planning, preparing and executing experiments. Students are expected to analyze the data generated in the experiments and to present the results in a written report.
Content	Experiments of this practical course cover a broad range of topics, including: • Optics: basic optical phenomena, optical elements, laser fundamentals • Physical Chemistry with special focus on light matter interaction: UV/Vis-absorption spectroscopy, fluorescence spectroscopy and vibrational spectroscopy • Physiology: selected experiments introducing into the of physiology and pharmacology
Course type	Practical course
ECTS credits	12
Category	Compulsory module
Usability	Module in the 1st and 2nd semester of the Medical Photonics program.
Frequency of offer	winter semester / summer semester
Duration	2 semesters
Work load	Total work load: 360 h
Language	English
Prerequisites	none
Exam prerequisites	regular labwork
Requirements to complete this module	Every student has to carry out 8 of the 9 experiments offered in the module and submit a written report. Similar experiments performed during the bachelor course can be recognized. The decision will be based on the student's transcript and a personal interview.
Used media	specified by the instructor
Literature	Prepared electronic material describing the labs and experiments. The material can be downloaded from the Medical Photonics homepage.

5.2. Module P 2: Research labwork (3rd semester)

Module number	MedPho – P 2
Module name	Research labwork
Coordinator	N.N.
Learning objectives	The aim of this module is to apply the knowledge and skills acquired during the first two semesters of the master's program to a specific research project. This includes: • carrying out a scientific project in medical photonics • analysis of the experimental results • 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	Compulsory module
Usability	Module in the 3rd semester of the Medical Photonics program.
Frequency of offer	winter semester
Duration	1 semester
Work load	Total work load: 540 h Depending on the topic this work load should be splitted as follows: • 150 h introduction to the research topic, study of relavant literature • 270 h research work • 100 h preparation of the final report/thesis • 20 h preparation of the presentation
Language	English
Prerequisites	completion of the modules in the first two semesters
Exam prerequisites	regular labwork
Requirements to complete this module	written report (approximately 20-30 pages) + oral presentation of the results The final grade will be determined on the performance during the research project (33%), the written report (33 %) and the presentation (33 %).
Used media	specified by the instructor
Literature	specified by the instructor

6. Master thesis

Module number	MedPho – M
Module name	Master thesis
Coordinator	N.N.
Learning objectives	The aim of this module is to apply the knowledge and skills acquired during the first three semesters of the master's program to a specific research project. This includes: • design of the experiment • analysis of the experimental results • preparation of a scientific report • presentation of the results in the master thesis and a presentation
Content	Internship in a research laboratory
Course type	Practical course
ECTS credits	30
Category	Compulsory module
Usability	Module in the 4th semester of the Medical Photonics program.
Frequency of offer	summer semester
Duration	1 semester
Work load	Total work load: 900 h Depending on the topic this work load should be splitted as follows: • 225 h introduction to the research topic • 450 h research work • 200 h preparation of the final report/thesis • 25 h preparation of the presentation
Language	English
Prerequisites	72 ECTS points and the completion of the modules "Adjustment", "Fundamentals" and "Specialization" offered in the first three semesters
Exam prerequisites	regular labwork
Requirements to complete this module	written report - master's thesis (66 %) + oral presentation of the results (33 %) examination at the end of the semester
Used media	specified by the instructor
Literature	specified by the instructor