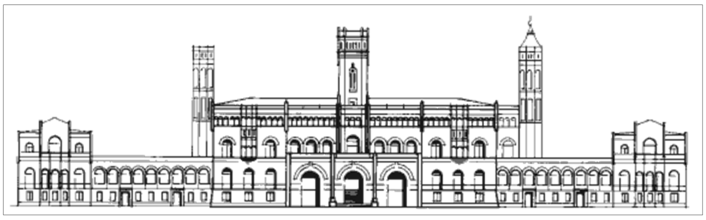
Physics Master's Program

Module Catalogue

Faculty of Mathematics and Physics

Leibniz University of Hanover



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Content:

Module Description

Program pathway

Semester / Area	1. Semester	2. Semester	3. Semester	4. Semester	CP
Advanced and Specialization Phase	**2 from 4 advanced studies modules (each 5 credit points):** - Advanced Solid State Physics - Advanced Gravitational Physics - Quantum Optics - Quantum Field Theory each L3+P1				10
	Lecture and/or Internship from the Physics Course Catalogue **Min. 31 credit points**				31
	Seminar course 3 credit points				3
Compulsory option	e.g. Chemistry, Meteorology, Hydrology, Geography, Informatics, Earth Sciences, Business Administration				16
Research Phase			**Research Internship 15 credit points** **Project Planning 15 credit points**	**Master Thesis Project 30 credit points**	60

Inhalt

Advanced Studies Phase

Advanced Solid State Physics			1221
Semester	Winter semester		
Responsible	Institute of Solid State Physics		
Courses (semester periods per week - SPW)	Lectures Advanced Solid State Physics (3 SPW) Practical Advanced Solid State Physics		
Assessment of credit points	**Required performance:** short tests and/or solving problems **Examination:** oral or written exam (lecturer's choice)		
Marking compound	Examination mark		
ECTS: 5 **Weight:** 1	**Attendance study (h):** 60	**Self-study (h):** 90	

Goals:
Students will acquire in-depth knowledge of theoretical models and experimental results in solid state physics. They will be enabled to classify selected phenomena and to develop models suited for their understanding. They get to know important developments in the field that evolved over the last decades and have a clear impression of actual unsolved problems in solid state physics. The students will be able to judge advantages and disadvantages of certain experimental techniques and acquire knowledge about the complementarity of various experimental possibilities.

Content:

- superconductivity
- dia- and paramagnetism
- ferro- and antiferromagetism
- magnetic resonance
- physics in systems of finite size
- physics in one and two dimensions, at surfaces and interfaces
- disorder: defects, alloys and glasses

Recommended Literature:

- 🕮 Ashcroft, Mermin, *Festkörperphysik*, Oldenbourg Verlag
- 🕮 Ch. Kittel, *Einführung in die Festkörperphysik*, Oldenbourg Verlag

Recommended Prerequisite Knowledge:

- Introduction in the Solid State Physics

If applicable, admission Prerequisite and a limited number of participants : none

Gravitational Physics			**1421**
Semester	Summer semester		
Responsible	Institute of Gravitational Physics		
Courses (SPW)	Lecture Gravitational Physics Practical Gravitational Physics		
Assessment of credit points	**Required performance:** practical exercise **Examination:** oral or written exam (lecturer's choice)		
Marking compound	Examination mark		
ECTS: 5 **Weight:** 1	**Attendance study (h):** 60	**Self-study (h):** 90	

Goals:
Students understand the fundamental concepts of gravitational physics and can apply these independently to selected problems. They are familiar with advanced experimental methods in the field and can apply these under guidance.

Content:

- General relativity
- equivalence principle, Lense–Thirring effect
- Cosmology
- Astrophysics
- Sources and propagation of gravitational waves
- Laser interferometer
- Interferometer-recycling-technics
- modulation fields
- Homodyn- und Heterodyndetektion
- Control of Interferometer
- Optical, mechanical and thermic properties of mirrors and there dialectric surface coating

Recommended Literature:
to be announced in class

Recommended Prerequisite Knowledge:
- Foundation of Special Theory of Relativity
- Module Coherent Optics

If applicable, admission Prerequisite and a limited number of participants : none

Quantum Optics			1321
Semester	Winter semester		
Responsible	Institute of Quantum Optics		
Courses (SPW)	Lecture Quantum Optics Practical Quantum Optics		
Assessment of credit points	**Required performance:** practical exercises **Examination:** oral or written exam (lecturer's choice)		
Marking compound	Examination mark		
ECTS: 5 **Weight:** 1	**Attendance study (h):** 60	**Self-study (h):** 90	

Goals:
Students understand the fundamental concepts of quantum optics and can apply these independently to selected problems. They are familiar with advanced experimental methods in the field and can apply these under guidance.

Content:
- Quantisation of the electromagnetic field
- Quantum states of the electromagnetic field (Fock, Glauber and squeezed states)
- Heisenberg uncertainty relation (number/phase, amplitude/phase quadrature)
- Photon statistics, quantum noise
- Bell inequalities and nonlocality
- Generation of squeezing and entanglement
- Spontaneous emission, Lamb shift, Casimir effect
- Atom-field interaction with coherent fields, dressed states
- Photon scattering, Feynman diagrams
- Multiphoton processes
- Quantum theory of the nonlinear susceptibility
- Modern quantum optics experiments

Recommended Literature:
- Mandel/Wolf, *Optical Coherence and Quantum Optics,* Cambridge University Press
- Walls/Milburn, *Quantum Optics,* Springer
- Bachor/Ralph, *A Guide to experiments in Quantum Optics,* Wiley-VCH
- Schleich, *Quantum Optics in Phase space,* Wiley-VCH
- Original literature

Recommended Prerequisite Knowledge:
- Module Coherent Optics

If applicable, admission Prerequisite and a limited number of participants : none

Quantum Field Theory			**1121**
Semester	Winter semester or summer semester		
Responsible	Institut of Theoretical Physics		
Courses (SPW)	Lecture Quantum Field Theory Practical Quantum Field Theory		
Assessment of credit points	**Required performance:** practical exercises **Examination:** oral or written exam (lecturer's choice)		
Marking compound	Examination mark		
ECTS: 5 **Weight:** 1	**Attendance study (h):** 60	**Self-study (h):** 90	

Goals:
The student acquires a solid and formal understanding of quantum field theory and can autonomously apply its quantitative mathematical methods. He or she is able to deduce the physical content of the mathematical models and to interpret them in the context of established theories.
The student is familiar with the mathematical techniques and master analytical and numerical procedures suitable for problem solving in this field.

Content:
- Classical field theory
- Canonical field quantization (scalar field, Dirac field, vector field)
- Perturbation theory and Feynman rules
- Path-integral quantization (quantum mechanics, scalar field, coherent states)
- Renormalization (regularization, renormalization, effective action)
- Quantization of gauge theories (QED, Yang-Mills)
- Finite temperature & statistical mechanics

Recommended Literature:
- 🕮 M.E. Peskin & D.V. Schroeder, *An Introduction to Quantum Field Theory,* Westview Press
- 🕮 L. H. Ryder, *Quantum Field Theory,* Cambridge University Press
- 🕮 S. Weinberg, *The Quantum Theory of Fields*, Vols. I&II, Cambridge University Press
- 🕮 D.J. Amit, *Field Theory, the Renormalization Group and Critical Phenomena,* World Scientific Publishing Company
- 🕮 J. Cardy, *Scaling and Renormalization in Statistical Physics,* Cambridge University Press
- 🕮 J. Zinn-Justin, *Quantum Field Theory and Critical Phenomena,* Oxford University Press

Recommended Prerequisite Knowledge:
- Lecture course in Advanced Quantum Theory

If applicable, admission Prerequisite and a limited number of participants : none

Specialization Phase

Selected Topics of Modern Physics		1621
Semester	Winter semester or summer semester	
Responsible	All Institutes of Physics	
Courses (SPW)	Courses amounting to min. 31 credit points according to the lecture timetable	
Assessment of credit points	**Required performance:** according to §14 from the Examination Regulation **Examination:** oral exam	
Marking compound	Oral examination mark	
ECTS: 31 **Weight:** 1	**Attendance study (h):**	**Self-study (h):**
Goals: Student will acquire a broad overview of modern physics on an advanced level, and will be able to classify this knowledge within the general context of physics. Within this module they will also exemplarily go into greater depth in a special subject of physics, which will enable them to join a research group working in this field on their master thesis.		
Content: Advanced courses of physics according to the choice of the student. The exam will cover the contents of thematically connected courses of at least 12 CP.		
Recommended Literature: To be announced in class		
Recommended Prerequisite Knowledge: Description of each course in the module catalogue		
If applicable, admission Prerequisite and a limited number of participants : none		

Course			**1622**
Semester	Winter semester oder summer semester		
Person Responsible	Institutes of Physics		
Courses (SPW)	Course		
Assessment of credit points	**Examination:** Corse participation		
Marking compound	Course mark		
ECTS: 3 **Weight:** 1	**Attendance study (h):** 30	**Self-study (h):** 60	

Goals:

- Students are able to research autonomously for a literature to a given actual issue from modern physics.
- Students are able to work out independently an actual science field.
- Students are able to structure and make a presentation about a complex issue from the modern physics, which could be followed by physical competent audience. By presenting the layout they are able to interest the audience for a complex special topic.
- Students are able to develop an appealing presentation (e.g. PowerPoint).
- Students are able to conduct a scientific discussion (on topics of their's own and their's classmates as well).
- Students are able to communicate fluently in German and English.

Content:
Advanced topics of physics

Recommended Literature:
To be announced in class

Recommended Prerequisite Knowledge:

If applicable, admission Prerequisite and a limited number of participants : none

Key skills for the englisch path of the Physics Master	**1970**
Semester	Winter and Summer semester
Person Responsible	Student Deanery
Courses (SPW)	According to the obligatory counseling, the students have to pass language courses in German in an extent of up to 10 CP. Classes from the offer by the Applied Linguistics and Special Languages (FSZ) or the Key Skills Centre (ZfSK) and relevant classes from the Faculties and computer classes offered by the computing centre (LUIS) as well.
Assessment of credit points	**Required performance:** according to §6 from the Examination Regulation
Marking compound	
ECTS: 10 **Weight:** 10	**Attendance and Self-study (h):** 120 -300

Kompetenzziele:
- You learn and handle exemplarily key skills in the field of the chosen class.

Inhalte:
- Topics according to the chosen class

Fundamental Literature:
- To be announced in class

Recommended knowledge:
- none

ggf. Eingangsvoraussetzungen und ggf. Teilnehmerzahlbegrenzung:
none

Verwendbarkeit:
- Masterstudiengang Physik
- Für alle anderen Studierenden umfasst dieses Modul 4 LP

Industrial Internship			1831
Semester	Winter semester or summer semester		
Responsible	Institutes of Experimental Physics		
Courses (SPW)	-		
Assessment of credit points	**Required performance:** Internship report		
Marking compound	-		
ECTS: 10	**Attendance study (h):**	**Self-study (h):**	

Goals:
Students are aware of typical task fields and scope of activities of graduates in technical physics in the professional practice. They are able to integrate into a working environment with scientists and engineers and to work in teams. They know exemplarily the implementation of scientific knowledge into an industrial process and understand the occurred task.

Content:
Internship at an industrial enterprise

Recommended Literature:

Recommended Prerequisite Knowledge:

If applicable, admission Prerequisite and a limited number of participants : none

Research Internship		**9031**
Semester	Winter and summer semester	
Responsible	Institutes of Physics and Meteorology	
Courses (SPW)	Internship: Research internship Class: Working group class	
Assessment of credit points	-	
Marking compound	-	
ECTS: 15	**Attendance study (h):** 450	

Goals:
Students are able to familiarize themselves with the measurement techniques or theoretical concepts of a field of research. They can develop an overview of the relevant literature related to a research project. Students are capable of working in a multi-national team and can communicate without problems in English and German.

Content:
- Literature research
- Getting acquainted with theoretical and experimental methods
- Discussion of current research topics in the research group seminar

Recommended Literature:
- 🕮 Relevant literature about current reasearch area
- 🕮 Abacus communications, *The language of presentations*, CDROM Lehr- und Trainingsmaterial
- 🕮 Alley, *The Craft of Scientific Presentation,* Springer

Recommended Prerequisite Knowledge:
- Advanced modules of the relative Master course

If applicable, admission Prerequisite and a limited number of participants : none

Project Planning			**9032**
Semester		Winter and summer semester	
Responsible		Institutes of Physics	
Courses (SPW)		Project: Project planning for Master thesis Class: Working group class	
Assessment of credit points		-	
Marking compound		-	
ECTS	15	**Attendance and self study (h):**	450

Goals:
The students have acquired social skills which enable them to be part of a research or development team. They are capable of performing independent scientific work and planning complex projects. Students can make their own inquiries and can develop an overview for example of the English literature and publications relevant for a research project.

Content:
- Definition of a scientific problem
- Methods of project management
- Conceiving, presenting and discussing a project plan

Recommended Literature:
- 🕮 Stickel-Wolf, Wolf, *Wissenschaftliches Arbeiten und Lerntechniken*, ISBN: 3-409-31826-7, Gabler Verlag
- 🕮 Steinle, Bruch, Lawa, (Hrsg.), *Projektmanagement: Instrument moderner Dienstleistung*, 1995, ISBN 3-929368-27-7, FAZ
- 🕮 Little, (Hrsg.), *Management der Hochleistungsorganisation*, Gabler Verlag, Wiesbaden, 1990

Recommended Prerequisite Knowledge:
- Advanced module of the relative Master course
- Module Research training

If applicable, admission Prerequisite and a limited number of participants : none

Comprehensive Exam, Research Training / Project Planning	**9033**
Semester	Winter and summer semester
Responsible	Institutes of Physics
Courses (SPW)	Required performance: Corse participation
Assessment of credit points	Examination: Project work
Marking compound	does not effect the Master mark
Weight:	0

Goals:
The student can acquire an overview of the scientific literature pertaining to a research project. He or she is able to conduct a scientific presentation and to describe his or her own research project in relation to the current state of the field.

Content:
Project planning, research training

If applicable, admission Prerequisite and a limited number of participants : none

Master Thesis		**9021**
Semester	Winter and summer semester	
Responsible	Institutes of Physics	
Courses (SPW)		
Assessment of credit points	**Examination**: Master thesis	
Marking compound	Master thesis mark	
ECTS **Weight Physics:** 30 5	**Attendance and self study (h):**	900

Goals:
Students are able to work independently on a research project. They are able to structure, prepare and conduct scientific projects under guidance. They are able to provide an overview of a literature and they analyze and solve komplex problems. Students are able to conduct critical discussions on other‘s and their's own research results and they can handle constructively questions and critics. Students are able to use fluently technical German and English language. They are able to make a scientific presentation and to present their own results in the context of the actual scientific knowledge and progress.

Content:
- Independent processing of an actual scientific problem definition in an international research environment
- Written documentation and oral presentation of the reasearch project and the results
- Scientific discussion of the results

Recommended Literature:
- 🕮 Relevant literature about current scientific problem definition
- 🕮 Day, *How to write & publish a scientific paper*. Cambridge University Press
- 🕮 Walter Krämer, *Wie schreibe ich eine Seminar- oder Examensarbeit?*, 1999, ISBN: 3-593-36268-6, Gruppe: Studienratgeber, Reihe: campus concret, Band: 47.

Recommended Prerequisite Knowledge:
-

If applicable, admission Prerequisite and a limited number of participants:
- Project planning

Regular Courses in Physics

Advanced Quantum Theory

Credit hours per week 3+1	**Credit points (ECTS):** 5	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Summer semester

Content:

- Many-particle systems: identical particles, Fock space, field quantization
- Open quantum systems: density operator, measurement process, Bell inequalities
- Information and thermodynamics: partition functions, entropy, thermodynamic equilibrium
- Semiclassical approximation: Bohr-Sommerfeld, tunneling, path integral
- Relativistic quantum mechanics: spcae-time symmetries, Dirac equation
- Scattering theory

Fundamental Literature:

- 🕮 W. Greiner and J. Reinhardt, *Theoretische Physik 7 (Quantenelektrodynamik) und 7a (Feldquantisierung),* Springer
- 🕮 R.H. Landau, *Quantum Mechanics II, A Second Course in Quantum Theory*, Wiley-VCH
- 🕮 A. Peres, *Quantum Theory: Concepts and Methods,* Springer
- 🕮 M.E. Peskin & D.V. Schroeder, *An Introduction to Quantum Field Theory,* Westview Press
- 🕮 J.J. Sakurai, *Modern Quantum Mechanics,* Addison Wesley
- 🕮 F. Schwabl, *Quantenmechanik für Fortgeschrittene,* Springer

Recommended knowledge:

- Mathmatics for Physicist

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Seminar Advanced Quantum Theory

Credit hours per week	**Credit points (ECTS):**	**Responsibility:**
2	3	Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Summer semester

Content:
In agreement with the lecturer. The seminar has to be attended in connection with the lecture course on Advanced Quantum Theory.

Fundamental Literature:

- W. Greiner and J. Reinhardt, *Theoretische Physik 7 (Quantenelektrodynamik) und 7a (Feldquantisierung),* Springer
- R.H. Landau, *Quantum Mechanics II, A Second Course in Quantum Theory,* , Wiley-VCH
- A. Peres, *Quantum Theory: Concepts and Methods*, Springer
- M.E. Peskin & D.V. Schroeder, *An Introduction to Quantum Field Theory,* Westview Press
- J.J. Sakurai, *Modern Quantum Mechanics,* Addison Wesley
- F. Schwabl, *Quantenmechanik für Fortgeschrittene,* Springer

Recommended knowledge:

- Mathmatics for Physicist

Modulzugehörigkeit:

- Modern Aspects of Physics
- Selected Topics of Modern Physics
- Seminar

Computational Physics

Credit hours per week 2+2	**Credit points (ECTS):** 6	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Winter- or Summer semester

Content:

- Basic numerical methods (differentiation, integration, interpolation, non-linear equations, systems of linear algebraic equations, Monte Carlo integration)
- Numerical solution of typical problems in physics (differential equations eigenvalue problems, optimization integration and sums of many variables)
- Applications to mechanics, electrodynamics and thermodynamics
- Data analysis (statistics, fit, extrapolation, spectral analysis)
- Visualization (graphical representation of data)
- Introduction to the simulation of physical systems (dynamical systems, simple molecular dynamics)
- Computer algebra

Fundamental Literature:

- Wolfgang Kinzel und Georg Reents, „*Physik per Computer*", Spektrum Akademischer Verlag
- S.E. Koonin and D.C. Meredith, „*Computational Physics",* Addison-Wesley
- W.H. Press, S.A. Teukolsky, W.T. Vetterling, B.P. Flannery, „*Numerical Recipes in C++",* Cambridge University Press
- J.M. Thijssen, „*Computational Physics",* Cambridge University Press
- Tao Pang, *„An Introduction to Computational Physics",* Cambridge University Press
- S. Brandt, „*Datenanalyse",* Spektrum Akademischer Verlag
- V. Blobel und E. Lohrmann, „*Statistische und numerische Methoden der Datenanalyse*", Teubner Verlag
- R.H. Landau, M.J. Paez, and C.C. Bordeianu, *Computational Physics*, Wiley-VCH, 2007

Recommended knowledge:

- Experience with computers and basics programming knowledge
- Analysis I+II
- Theoretical Electrodynamics
- Analytical Mechanics and Special Relativity
- Introduction to Quantum Mechanics

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Theoretical solid-state physics

Credit hours per week 3+1	**Credit points (ECTS):** 5	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Winter – or Summer semester (changing with Statistical field Theory)

Content:

- Transport
- Electronic correlations
- Low-dimensional systems
- Magnetism
- Superconductivity
- Disorder and impurities
- Mesoscopic systems

Fundamental Literature:

- 🕮 P.G. deGennes*, Superconductivity of Metals and Alloys, Perseus Publishing, 1999,* Westview Press
- 🕮 C. Kittel*: Quantum Theory of Solids,* Wiley
- 🕮 W. Nolting: *Quantentheorie des Magnetismus, Band I + II*, Teubner Verlag
- 🕮 J.M. Ziman*, Electrons and Phonons,* Oxford University Press, 2000
- 🕮 H. Bruus and K. Flensberg*, Many Body Quantum Theory in Condensed Matter Physics (*Oxford University Press, 2004)

Recommended knowledge:

- Advanced Qunatum Theory
- Quantum Field Theory

Module Affiliation:

- Selected Topics of Modern Physics

Statistical field Theory

Credit hours per week 3+1	**Credit points (ECTS):** 5	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Winter – or Summer semester (changing with Theoretocal solid-state physics)

Content:

- Partition function as a path integral
- Critical phenomena
- Condensed matter in two dimensions
- Quantum spin chains
- Non-equilibrium phenomena

Basic Literature:

📖 A. Altland and B. Simons, *Condensed Matter Field Theory (*Cambridge University Press, 2006*)*

📖 H. Bruus and K. Flensberg, *Many Body Quantum Theory in Condensed Matter Physics (*Oxford University Press, 2004)

📖 J.M. Thijssen, *Computational Physics* (Cambridge University Press, 2007)

📖 D. J. Amit & V. Martin-Mayor*: Field theory, the renormalization, group, and critical phenomena (*World Scientific 2005)

📖 G. Mussardo*: Statistical field theory: An introduction to exactly solved models in statistical physics, (Oxford 2010)*

📖 A. M. Tsvelik: *Quantum field theory in condensed matter physics,* (Cambridge 2003)

Recommended Prerequisites:

- Advanced Quantum Theory
- Quantum Field Theory

Module Affiliation:

- Selected Topics of Modern Physics

Seminar Condensed matter theory

Credit hours per week 2	**Credit points (ECTS):** 3	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Winter – or Summer semester

Content:
In consultation with the teachers. This seminar can only be taken in conjunction with the courses Theoretical solid-state physics or Statistical field theory.

Fundamental Literature:

📖 See the references for the courses Theoretical solid-state physics and Statistical field theory

Recommended knowledge:

- Advanced Quantum Theory
- Quantum Field Theory

Module Affiliation:

- Selected Topics of Modern Physics
- Seminar

Advanced computational physics

Credit hours per week 4+2	**Credit points (ECTS):** 8	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Winter – or Summer semester

Content:

- Exact diagonalizations
- Monte Carlo simulations
- Numerical renormalization group methods
- Density functional theory
- Molecular dynamics
- Quantum dynamics

Fundamental Literature:

- 🕮 J.M. Thijssen*, Computational Physics* (Cambridge University Press, 2007*)*
- 🕮 - S.E. Koonin and D.C Meredith*, Computational Physics,* Addison-Wesley, 1990.
- 🕮 - T. Pang*, Computational Physics*, Cambridge University Press, 2006
- 🕮 - H. Gould, J. Tobochnik, and W. Christian*, Computer Simulation Methods*, Pearson Education, 2007

Recommended knowledge:

- Introduction to Quantum Theory
- Statistical Mechanics
- Computational Physics

Module Affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Current problems in condensed matter theory

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Winter – or Summer semester

Content:

Current topics at the teacher's option:

- Theory of magnetism
- Theory of superconductivity
- Theory of the quantum Hall effect
- Theory of strongly correlated electrons
- Integrable quantum systems
- Systems out of equilibrium

Fundamental Literature:

wird vom Dozenten angegeben

Recommended knowledge:

- Advanced Quantum Theory
- Advanced Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics

Theory of Fundamental Interactions

Credit hours per week 3+1	**Credit points (ECTS):** 5	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Winter- or Summer semester

Content:

Varying topics, will be chosen by the lecturer, for example:

- String Theory
- Supersymmetry
- General Relativity
- Gauge Theory and its Quantization
- Conformal Field Theory

Fundamental Literature:

- 🕮 Peskin, Schröder, *Quantum Field Theory,* Westview Press
- 🕮 Wess, Bagger, *Supersymmetry and Supergravity,* Princeton University Press
- 🕮 Galperin, Ivanov, Ogievetsky, Sokatchev, *Harmonic Superspace,* Cambridge University Press
- 🕮 Green, Schwarz, Witten, *Superstring Theory,* Cambridge University Press
- 🕮 und aktuelle Forschungspublikationen

Recommended knowledge:

- Advanced Quantum Theory

Module Affiliation:

- Selected Topics of Modern Physics

Seminar Theory of Fundamental Interactions

Credit hours per week 2	**Credit points (ECTS):** 3	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Winter- or Summer semester

Content:
In agreement with the lecturer. The seminar has to be attended in connection with the lecture course on Theory of Fundamental Interactions.

Fundamental Literature:

- 🕮 Peskin, Schröder, *Quantum Field Theory,* Westview Press
- 🕮 Wess, Bagger, *Supersymmetry and Supergravity,* Princeton University Press
- 🕮 Galperin, Ivanov, Ogievetsky, Sokatchev, *Harmonic Superspace,* Cambridge University Press
- 🕮 Green, Schwarz, Witten, *Superstring Theory,* Cambridge University Press
- 🕮 und aktuelle Forschungspublikationen

Recommended knowledge:

- Advanced Quantum Theory

Module Affiliation:

- Selected Topics of Modern Physics
- Seminar

Advanced Topics in Classical Physics

Credit hours per week 3+1	**Credit points (ECTS):** 5	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Winter – or Summer semester

Content:

Selected areas of classical physics, chosen by the lecturer, for example:

- General Relativity: Minkowski space, Lorentz group, its representations, relativistic particles, coupling to the electromagnetic field, Liénard-Wiechert potentials, Schwarzschild metric, tests of General Relativity in the solar system, Thirring-Lense effect, deflection of light, Einstein-Hilbert action, covariant energy-momentum conservation, gravitational waves: generation and detection, cosmology
- Gauge Theories: Parallel transport, covariant derivative, field strength, holonomy group, Bianchi identities, action principle, Noether identities, algebraic Poincaré lemma, the Standard Model of fundamental interactions, monopoles, spontaneous symmetry breaking, BRS symmetry, anomalies
- Integrable and Chaotic Motion: Hamiltonian equations of motion, canonical transformations, Poincaré's integral invariants, action-angle variables, perturbation theory, Kolmogorov-Arnol'd-Moser theorem, Poincaré recurrence, Birkhoff's fixpoint theorem, self-similar Hamiltonian flow

Fundamental Literature:

📖 B. F. Schutz, *A first course in general relativity*, Cambridge University Press

📖 W. Rindler, *Relativity*, Oxford University Press

📖 V. Mukhanov, *Physical Foundations of Cosmology*, Cambridge University Press

📖 L. O'Raifeartaigh, *Group Structure of Gauge Theories,* Cambridge University Press

📖 V. Arnol'd, *Mathematical Methods of Classical Mechanics,* Springer

📖 A. J. *Lichtenberg and M. A. Liebermann, Regular and Stochastic Motion,* Springer

📖 J. Moser, *Stable and Random Motion in Dynamical Systems*, Princeton University Press

Recommended knowledge:

- Analytical Mechanics and Special Relativity

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Solid State Physics in lower dimensions

Credit hours per week	Credit points (ECTS):	Responsibility:
3+1	5	Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

- Production of structures lower dimension, epitaxy
- Electronical characteristics in 0 to 2 dimensions
- Effects of the electron correlations
- Resonant units
- Magnetic characteristics
- One-dimensional chains: dispersion, instability, defects
- Solitons
- Supercondoctivity in strong anisotropic systems
- Charge- and spin-density-waves

Fundamental Literature:

- 🕮 Roth, Carroll, *One-dimensional metals*, VCH
- 🕮 I. Markov, *Crystal growth for beginners*, World Scientific
- 🕮 R. Waser, *Nanotechnology*, Wiley-VCH

Recommended knowledge:

- Introduction to the solid state physics

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Lab course to Solid State physics in lower dimensions

Credit hours per week 3	**Credit points (ECTS):** 3	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

Possible Experiments: Quantum Hall effect, Epitaxy, vacuum technology, diffractions of slow electrones, tunneling microscopy and spectroscopy. The Lab course has to be chosen together with the lecture class Solid State physics in lower dimensions.

Fundamental Literature:

- Roth, Carroll, *One-dimensional metals*, VCH
- I. Markov, *Crystal growth for beginners*, World Scientific
- R. Waser, *Nanotechnology*, Wiley-VCH

Recommended knowledge:

- Introduction in the Solid state Physics

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Surface and interface physics

Credit hours per week	**Credit points (ECTS):**	**Responsibility:**
3+1	5	Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

- Structure of solid state surfaces and methods
- Electronic properties of interfaces and methods
- Bonding of atoms and molecules on surfaces
- Simple reaction kinetics
- Structuring and self-assembly
- Defects and their physical impact

Fundamental Literature:

- 🕮 Zangwill, *Physics at Surfaces*, Cambridge University Press
- 🕮 M. Henzler, M. Göpel, *Oberflächenphysik des Festkörpers*, Teubner
- 🕮 F. Bechstedt, *Principles of surface physics*, Springer
- 🕮 Ph. Hoffmann, Wiley

Recommended knowledge:

- Introduction to Solid State Physics
- Advanced Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics

From atoms to solids

Credit hours per week 3+1	**Credit points (ECTS):** 5	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

- Generation of low-dimensional structures, epitaxy
- electronic properties in 0 to 2 dimensions
- Consequences of electron correlation
- resonant electronic devices
- magnetic properties
- one-dimensional chains: dispersion, instabilities defects
- solitons
- superconductivity on strongly anisotropic systems
- charge and spin density waves

Fundamental Literature:

- 🕮 Roth, Carroll, *One-dimensional metals*, Wiley-VCH
- 🕮 R. Waser, *Nanotechnology*, Wiley-VCH
- 🕮 U. Bovensiepen, H. Petek, M. Wolf: *Dynamics at solid state surfaces and interfaces, Wiley-VCH*

Recommended knowledge:

- Introduction to Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Course to From atoms to solids

Credit hours per week	Credit points (ECTS):	Responsibility:
2	3	Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

According to the agreement with the instructor. The course has to be taken in combination with the lecture From atoms to solids.

Fundamental Literature:

- Roth, Carroll, *One-dimensional metals*, VCH
- I. Markov, *Crystal growth for beginners*, World Scientific
- R. Waser, *Nanotechnology*, Wiley-VCH

Recommended knowledge:

- Introduction to Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics
- Seminar

Semiconducter Physics

Credit hours per week	Credit points (ECTS):	Responsibility:
2+1	4	Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Winter Semester

Content:

- Energy band
- Electric transport
- Defects
- Optical Property
- Quantum Confinement
- P-n-junctions, bipolar transistors
- Field effect transistors
- Manufacturing techniques

Fundamental Literature:

- 🕮 P.Y. Yu, M. Cardona, *Fundamentals of Semiconductors*, Springer
- 🕮 S.M. Sze, *Semiconductor devices, Physics and Technology*, Wiley, New York

Recommended knowledge:

- Introduction to Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics

Semiconductor characterization techniques for photovoltaics

Credit hours per week 2	**Credit points (ECTS):** 3	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Winter semester

Content: In this lecture we discuss different characterization techniques which are used to assess each process step during the production of crystalline silicon solar cells from a silicon ingot. In particular, these are techniques for:

- Materials characterization: conductivity, charge carrier density, charge carrier lifetime (photoluminescence, photoconductivity, thermography), defects (deep level transient spectroscopy, charge carrier lifetime spectroscopy, infrared spectroscopy), crystal orientation (electron back scattering diffraction)
- Process characterization: doping profile (electrochemical capacitance voltage profliling), texturing (scanning electron microscope, reflection), charge carrier lifetime (photoluminescence, photoconductivity, thermography), layer thickness und refractive index (ellipsometry, infrared spectroscopy)
- Solar cell characterization: current-voltage-curve, quantum efficiency, reflection, shunt analysis (thermography), series resistant (transmission line method, Photolumineszenz)

Recommended literatures:

- 🕮 *D.K. Schroder*, Semiconductor Material and Device Characterization (2nd ed.), Wiley (1998)
- 🕮 *S. M. Sze*, Semiconductor Devices: Physics and Technology, Wiley (1985)
- 🕮 *Bergmann, Schaefer*, Lehrbuch der Experimentalphysik Bd. 6: Festkörper, de Gruyter (1992)

Recommended knowledge:

- Introduction to solid state physics
- Semiconductor physics
- Physics of solar cells

Module Affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Scanning Probe Technology

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Winter semester

Content:

- Scanning tunnel microscopy
- State density and transmission probabilties
- Scanning tunnel spectroscopy
- Atomic force microscopes
- Occuring forces on surfaces
- Detection of local electrical and magnetic fields
- Friction images
- Scanning electron microscopy

Fundamental Literature:

- E. Meyer; H. J. Hug, R. Bennewitz, *Scanning probe microscopy : the lab on a Tipp*, Springer
- B. Bushan, *Applied scanning probe methods*, Springer

Recommended knowledge:

- Introduction to solid state physics

Module Affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Molecular electronics

Credit hours per week 2V **+ 1Ü**	**Credit points (ECTS):** 4	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

- Geometric and electronic structure of molecules
- molecular crystals
- organics films, doping, electronic transport in organic material, OLED
- molecules on surfaces
- one-dimensional molecular structures
- instabilities, charge and spin density waves, solitons
- atomistic contacts and quantized transport
- transport through single molecules

Fundamental Literature:

- 🕮 J. Tour, *Molecular electronics*, World scientific 2002
- 🕮 M. Schwoerer, H.C. Wolf: *Organic molecular solids*, Wiley-VCH 2007 (also in german)
- 🕮 J.C. Cuevas, E. Scheer: *Molecular electronics: an introduction to theory and experiment,* World Scientific 2010

Recommended knowledge:

- Introduction to solid state physics

Module Affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Methods of surface analysis

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

- Vakuum techniques and sample preparation
- Methods fort he chemcial analysis:
  XPS, UPS, AES, EELS, ISS, TDS, ESD
- Determiniation of the geometric structure:
  STM, AFM, FIM, LEED, SEM
- Analysis of the electron structure:
  UPS, XPS, IPESD, NEXAFS

Fundamental Literature:

- 🕮 D.P. Woodruff, T.A. Delchar, *Modern Techniques of Surface Sciencem,* Cambridge University Press
- 🕮 H. Bubert , H. Jenett, *Surface and Thin Film Analysis,* Wiley-VCH
- 🕮 Springer Series in Surface Science

Recommended knowledge:

Introduction to solid state physics

Module Affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Laboratory course in Surface Science methods

Credit hours per week 3	**Credit points (ECTS):** 3	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

Appropriate experiments, e.g. XPS, UPS, LEED, EELS, STM, AFM. The lab course should be attended together with the Surface Science lecture.

Fundamental Literature:

- D.P. Woodruff, T.A. Delchar, *Modern Techniques of Surface Science,* Cambridge University Press
- H. Bubert , H. Jenett, *Surface and Thin Film Analysis,* Wiley-VCH
- Springer Series in Surface Science

Recommended knowledge:

- Introduction to Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics
- Modern Aspects of Physics

Physics in nanostructures

Credit hours per week 3+1	**Credit points (ECTS):** 5	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

- Preparation of nanostructures by lithography and self-assembly
- Electronic structure, interface states, heterostructures
- Quantum size effects
- Transport signatures in mesoscopic systems
- Magneto resistance effects
- Quantum Hall effect
- New 2D materials: graphene and topological insulators
- Instabilities in 1-dimensional structures
- Single electron transistors
- Molecular electronics
- Experimental methods

Fundamental Literature:

- 🕮 Crystal Growth for Beginners, Ivan V Markov (World Scientific)
- 🕮 Mesoscopic Electronics in Solid State Nanostructure, Thomas Heinzel (Wiley)
- 🕮 Surface Science: An Introduction, Philip Hofmann (kindle.edition)
- 🕮 Nanoelectronics and Information Technology, Rainer Waser (Wiley)

Recommended knowledge:

- Introduction to Solid State Physics
- Surface Physics

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Optical Spectroscopy of solids

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Winter semester

Content:

- Short-pulse-laser
- Light-matter-interaction
- Pumps-request Techniques
- Time resolved photoluminescence
- Polarisation (Jones-matrix, Stokes-vector)
- Semiconductor optics
- Physical limits of time resolution and measuring sensitivity
- Noises as measurand

Fundamental Literature:

- 🕮 Jean-Claude Diels, Wolfgang Rudolph, *„Ultrashort Laser Pulse Phenomena",* Academic Press
- 🕮 C. Klingshirn, *„Semiconductor Optics" Second Edition,* Springer

Recommended knowledge:

- Introduction to Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics

Quantum Devices

Credit hours per week 3+1	**Credit points (ECTS):** 5	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

- Quantum effects in semiconducting structures
- Physics of two dimensional electron gases
- Quantum wires
- Quantum dots
  Coherence and interaction effects
- Single electron transistor
- Quantum computing

Fundamental Literature:

- C. Weisbuch, B. Vinter, *Quantum Semiconductor Structures,* Academic Pr Inc
- S.M. Sze, *Semiconductor Devices: Physics and Technology,* Wiley
- M.J. Kelly, *Low-Dimensional Semiconductors: Materials, Physics, Technology, Devices,* Oxford University Press

Recommended knowledge:

- Introduction to solid state physics
- Advanced solid state physics

Module Affiliation:

- Selected Topics of Modern Physics

Physics of solar cells

Credit hours per week 2+2	**Credit points (ECTS):** 6	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

- Fundamentals of semiconductor physics
- Optical properties of semiconductors
- Transport of electrons and holes
- Mechanisms of charge carrier recombination
- Manufacturing process for solar cells
- Characterization methods for solar cells
- Possibilities and limitations for efficiency improvements

Recommended literatures:

- 🕮 P. Würfel, *„Physics of solar cells"* (WILEY-VCH Verlag GmbH & Co, 2005).
- 🕮 A. Goetzberger, J. Knobloch, „Crystalline Silicon Solar Cells" (John Wiley & Sons, 1998).

Prior knowledge:

- Introduction to Solid State Physics

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Practical laboratory course for advanced solar energy research

Credit hours per week	Credit points (ECTS):	Responsibility:
3	3	Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Winter semester

Content:

- The students fabricate a simple semiconductor test structure (e.g. a p-type Si sample with a ohmic and a MIS contact via thermal evaporation)
- Characterization of test structures with common measurement techniques for solar cells (e.g. current-voltage curve with variable temperature and different light intensities; spectrally resolved quantum efficiency; charge carrier lifetime; spectrally resolved optical reflection)
- Determination of recombination parameters by analyzing data from experiments.
- Estimation of the accuracy of the parameter determination by applying error calculation.
- Each aspect of laboratory exercises will be discussed at a seminar, offering the students the opportunity to deepen their theoretical knowledge.
- The experimental results of laboratory exercises will be presented at the seminar.

Recommended literatures:

- 🕮 D. K. Schroder, *"Semiconductor Material and Device Characterization",* 2nd Edition (Wiley, 1998).
- 🕮 Fahrenbruch, R. Bube*: "Fundamentals of Solar Cells"* (Academic Press, 1983).
- 🕮 M. A. Green, *"High Efficiency Silicon Solar Cells"* (Trans Tech Publications, 1987).
- 🕮 R. Brendel, *"Thin-Film Crystalline Silicon Solar Cells - Physics and Technology"*, (Wiley-VCH, 2003)

Prior knowledge:

- Introduction to Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics

Seminar for advanced solar energy research

Credit hours per week 2	**Credit points (ECTS):** 3	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Winter semester

Content:

- In this seminar, the students present the experimental results of laboratory exercise.
- Each aspect of laboratory exercises will be discussed in order to deepen the theoretical knowledge.

This seminar must be attended in association with the practical laboratory course for advanced solar energy research.

Recommended literatures:

- 🕮 D. K. Schroder*, "Semiconductor Material and Device Characterization",* 2nd Edition (Wiley, 1998).
- 🕮 Fahrenbruch, R. Bube*: "Fundamentals of Solar Cells"* (Academic Press, 1983).
- 🕮 M. A. Green*, "High Efficiency Silicon Solar Cells"* (Trans Tech Publications, 1987).
- 🕮 R. Brendel*, "Thin-Film Crystalline Silicon Solar Cells - Physics and Technology"*, (Wiley-VCH, 2003)

Prior knowledge:

- Introduction to Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics
- Seminar

Lab course Solid State Physics

Credit hours per week	Credit points (ECTS):	Responsibility:
6	6	Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Winter- and Summer semester

Content:

- Quantum Hall effect
- Epitaxy
- Vacuum techniques
- Binding at surfaces and interfaces
- Diffraction methods with x-rays and slow electrons
- tunneling microscopy and –spectroscopy
- Nanostructuring, electron beam lithography
- electron microscopy
- Resonant tunneling

Fundamental Literature:

will be given during the course

Recommended knowledge:

- Introduction to Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics

Course Current Research Topics of the solid state physics

Credit hours per week 2	**Credit points (ECTS):** 3	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Summer semester

Content:

Problems of the current Research, e.g. from the topics:

- Ultrathin metallic layers
- Phase transistions in two dimensions
- Molecular electronics
- Defect analysis in silicon wafers
- Isolator epitaxie
- Nanostructured metal/isolator system
- Electron-beam lithography
- Structuring of semiconducter components with atomic force microscope
- Resonant tunnel through InAs quantum dots
- High frequency experiments in quantum hall effect
- Electron- phonon-correlation in quantum hall sysytems
- Transport experiments in Si/SiGe heterostructure
- Noises in low dimensional electronic system
- Spintronics in semiconducters
- Optics in quantum hall regime

Fundamental Literature:

Will be announced to every topic

Recommended knowledge:

- Advanced solid state physics

Module Affiliation:

- Seminar

Nonlinear Optics

Credit hours per week 3+1	**Credits:** 5	**Responsibility** Institute of Quantum Optics (Institut für Quantenoptik)

Cycle: Summer Semester

Content:

- Nonlinear optical susceptibility
- Crystal optics, tensor optics
- Wave equation with nonlinear source terms
- Frequency doubling, sum-, difference-frequency generation
- Optical parametric amplifier, oscillator
- Phase-matching schemes, quasi phase-matching
- Electro-optical effect
- Electro-acoustic modulator
- Frequency tripling, Kerr-effect, self-phase modulation, self-focusing
- Raman-, Brillouin-scattering, four wave mixing
- Nonlinear propagation, solitons

Fundamental Literature:

- Agrawal, *Nonlinear Fiber optics*, Academic Press
- Boyd, *Nonlinear Optics*, Academic Press
- Shen, *Nonlinear Optics,* Wiley-Interscience
- Dmitriev, *Handbook of nonlinear crystals*, Springer
- Originalliteratur

Recommended knowledge:

- Atom and molecular physics

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Photonics

Credit hours per week	ECTS credits:	Responsibility
2+1	4	Institute of Quantum Optics (Institut für Quantenoptik)

Regularity: Winter semester

Content:

- Waves in Media and at Boundaries
- Dielectric Waveguides (planar, fiber), Integrated Waveguides
- Waveguide Modes
- Nonlinear Fiber Optics
- Fiber optic components (Cirkulators, AWG, Fiber-Bragg-Gratings, Modulators), Optical Communication (WDM/TDM)
- Faserlaser
- Laserdiods, Photodetectors
- Plasmonics, Photonic Crystals
- Transformation Optics

Relevant Literature:

- 🕮 Saleh, Teich: Photonics, Wiley;
- 🕮 Maier: Plasmonics: Fundamentals and Applications, Springer
- 🕮 Boyd: Nonlinear Optics, Academic Press
- 🕮 Original literature

Required Knowledge:

- Coherent Optics
- Nonlinear Optics

Relevant Modules:

- Selected Topics of Modern Physics
- Ausgewählte Themen der Photonik

Seminar Photonics

Credit hours per week	**ECTS credits:**	**Responsibility**
2	3	Institute of Quantum Optics (Institut für Quantenoptik)

Regularity: Winter semester

Content:
According to discussion with lecturers. The seminar has to be chosen in combination with the lecture Photonics.

Relevant Literature:

- 🕮 Saleh, Teich: Photonics, Wiley;
- 🕮 Maier: Plasmonics: Fundamentals and Applications, Springer
- 🕮 Boyd: Nonlinear Optics, Academic Press
- 🕮 Original literature

Required Knowledge:

- Coherent Optics
- Nonlinear Optics

Atom optics

Credit hours per week 2+1	**Credit points (ECTS):** 4	**Responsibility:** Institute of Quantum Optics (Institut für Quantenoptik)

Regularity: Summer semester

Content:

- Atom-light interaction Atom-Licht Wechselwirkung
- Radiation pressure forces Strahlungsdruckkräfte
- Neutral atom and ion traps Atom- und Ionenfallen
- Evaporative cooling Kühlung durch Evaporation
- Bose-Einstein Condensation Bose-Einstein-Kondensation
- Ultracold Fermi Gases Ultrakalte Fermi-Gase
- Experiments with ultracold and quantum degenerate gases Experimente mit ultrakalten und entarteten Quantengasen
- Atoms in optical lattices Atome in optischen periodischen Gittern
- ATOMICS and modern matter wave optics experiments ATOMICS und moderne Experimente zur Atomoptik

Fundamental Literature:

- B. Bransden, C. Joachain, *Physics of Atoms and Molecules*, Longman 1983
- R. Loudon, *The Quantum Theory of Light,* OUP, 1973
- Original research publications Aktuelle Publikationen

Recommended knowledge:

- Atomic and molecular physics Atom- und Molekülphysik
- Quantum optics Quantenoptik

Module Affiliation:

- Selected Topics of Modern Physics
- Ausgewählte Themen der Photonik

Lab course optics

Credit hours per week	Credits:	Responsible:
6 (lab course)	6	Institute of Quantum Optics (Institut für Quantenoptik)

Semester: Winter and summer semester

Content:

- Resonant power enhancement („Power-Recycling")
- Interferometric determination of gas density
- Magneto optical trap
- Fiber laser
- Dielectric coatings for optical components
- Saturation spectroscopy with diode lasers
- Optical tweezer
- Ultra short pulse laser

Fundamental Literature:

Will be specified in the lab course

Recommended knowledge:

- Coherent optics

Module Affilation:

- Modern aspects of physics
- Selected topics of modern physics

Data Analysis

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institute for Gravitational Physics (Institut für Gravitationsphysik)

Regularity: Summer semester

Content:

- Detectors (interferometer and „resonant mass“ detectors)
- Data analysis
- Templates
- vetoes

Fundamental Literature:

to be announced in class

Recommended knowledge:

- Basics of special relativity theory
- Coherent optics

Module Affiliation:

- Selected Topics of Modern Physics

Neutron Stars und Black Holes

Credit hours per week	**Credit points (ECTS):**	**Responsibility:**
2	2	Institute for Gravitational Physics (Institut für Gravitationsphysik)

Regularity: Summer semester

Content:

- Sources and expansion of gravitation waves
- Neutron stars and Black Holes

Fundamental Literature:

to be announced in class

Recommended knowledge:

- Basics of special relativity theory
- Coherent optics

Module Affiliation:

- Selected Topics of Modern Physics

Course Gravitation waves

Credit hours per week 2	**Credit points (ECTS):** 3	**Responsibility:** Institute for Gravitational Physics (Institut für Gravitationsphysik)

Regularity: Summer semester

Content:

In agreement with the professor

Fundamental Literature:

to be announced in lecture class and course

Recommended knowledge:

- Basics of special relativity theory
- Coherent optics

Module Affiliation:

- Selected Topics of Modern Physics

Course Gravitationaal Physics

Credit hours per week 3	**Credit points (ECTS):** 3	**Responsibility:** Institute for Gravitational Physics (Institut für Gravitationsphysik)

Regularity: Summer semester and Winter semester

Content:

- General Theory of relativity
- Sources of Gravitational waves
- Gravitational waves detectors
- Astrophysics and cosmology
-

Fundamental Literature:

to be announced in class

Recommended knowledge:

- Gravitational Physics

Module Affiliation:

- Selected Topics of Modern Physics
- Seminar

Laser Interferometry		
Credit hours per week 3	**Credit points (ECTS):** 3	**Responsibility:** Institute for Gravitational Physics (Institut für Gravitationsphysik)
Regularity: Summer semester or Winter semester (irregular)		

Content:

- Michelson-, Mach-Zehnder-, und Fary-Perot interferometer,
- Thermal noise
- Mechanical quality of hanging lenses
- Applications for measurement of Gravitational waves and the gravity field of the earth
- Description Gaussion rays and higher methods
- Transformation of Gaussion rays
- Selction procedures: internal, external and Schnuppmodulation; Pound-Drever Hall procedure
- Polarization
- Transfer function and control loops

Fundamental Literature:

- 🕮 Saulson, *Fundamentals of Interferometric GW detectors,* World Scientific Pub Co Inc
- 🕮 Siegman: Lasers
- 🕮 Yariv: Quantum Electronics r

Recommended knowledge:

Optics, complex linear algebra

Module Affiliation:

- Selected Topics of Modern Physics

Lab course Laser interferometry		
Credit hours per week 4	**Credit points (ECTS):** 4	**Responsibility:** Institute for Gravitational Physics (Institut für Gravitationsphysik)
Regularity: Summer semester or Winter semester (irregular)		
Content: • Michelson-, Mach-Zehnder-, Sagnac-, Polarization interferomtery, • "Power- and Signal recycling", "Resonant Sideband Extraction", „Delaylines" • Modulation fields, Schnuppmodulation, external modulation • Homodyne and Heterodyne detection • Spectral noise density • Interferometry noises and sensitives (Quantum-, thermal noises, …) • Mechanical quality of hanging lenses		
Fundamental Literature: 🕮 Saulson, *Fundamentals of Interferometric GW detectors,* World Scientific Pub Co Inc 🕮 Originalliteratur		
Recommended knowledge: • Coherent optics • Nonlinear opticschtlineare Optik		
Module Affiliation: • Selected Topics of Modern Physics		

Laser stabilization and control of optical experiments

Credit hours per week	**Credits:**	**Responsible**
2	2	Institute for Gravitational Physics (Institut für Gravitationsphysik)

Semester: irregular in winter or summer semester

Content:

- description of light fields and interference
- descriptions of fluctuations and noise
- basics of feedback control
- length control of interferometers and optical resonators
- detection of laser frequency fluctuations and their reduction
- detection of laser power fluctuations and their reduction
- pointing control of laser beams

Fundamental Literature:

- Lasers; Siegman, Anthony E; Mill Valley, Calif. Univ. Science Books;(1986);ISBN 0-935702-11-5
- Optical electronics in modern communications; Yariv, Amnon; New York, Oxford Univ. Press; (1997) ;ISBN 0195106261 (cl)
- Feedback control systems : a fast-track guide for scientists and engineers; Abramovici, Alex (Chapsky, Jake;); Boston, Kluwer Acad. Publ; (2000); ;ISBN 0792379357
- A. Freise und K. Strain: Interferometer Techniques for Gravitational Wave Detection, Living Rev. 13 (2010) http://relativity.livingreviews.org/Articles/lrr-2010-1/

Recommended knowledge:

coherent optics

Module Affiliation:

- special topics of modern physics

Labcourse Cluster Computing

Responsibility:
Institute for Gravitational Physics (Institut für Gravitationsphysik)

Regularity: Summer semester and Winter semester

Content:

- basics of matched filtering search method
- template banks and different search algorithms
- mismatch statistic and roc curves
- handle cluster resources using HTCondor
- computation time versus sensitivity of the analysis

Fundamental Literature:

- 🕮 to be announce in class

Recommended knowledge:

- Experience in Linux

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Non-classical Light

Credit hours per week	**Credits:**	**Responsible**
2	2	Institute for Gravitational Physics

Semester: Winter semester, (irregular)

Topics:
classical and non-classical states of light
criteria for "non-classicity"
detection and generation of Fock states
detection and generation of squeezed light
quantum state tomography
EPR entangled (two-mode squeezed) light
optical test of non-locality

Fundamental Literature:

- 🕮 C.C. Gerry und P.L. Knight, *Introductory Quantum Optics*, University Press, Cambridge (2005).
- 🕮 H.-A. Bachor und T.C. Ralph, *A guide to experiments in quantum optics*, Wiley, 2nd edition (2003).

Recommended knowledge:

coherent optics
non-linear optics
non-classical light
quantum optics

Module Affiliation:

- Selected Topics of Modern Physics

Non-classical Laser Interferometry

Credit hours per week	**Credit points**	**Responsible Institution**
2+2	5	Institute for Gravitational Physics

Recurrence: Summer semester, (irregular)

Topics:

- shot noise and radiation pressure noise in interferometers
- quadrature operators and "input-output" relations of interferometers
- the standard quantum limit of position measurements
- quantum non-demolition techniques
- interferometers with squeezed light and other non-classical states of light
- opto-mechanical coupling and optical springs
- quantum states of mechanical oscillators
- cooling of mechanical oscillators to their quantum mechanical ground state
- entanglement of mirrors and light

Fundamental literature:

- 🕮 Saulson, *Fundamentals of Interferometric GW detectors,* World Scientific Pub Co Inc
- 🕮 Original literature

Recommended knowledge:

coherent optics
non-linear optics
non-classical light
quantum optics

Module Affiliation:

- Selected Topics of Modern Physics

Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institute for Radioecology and Radiation Protection

Regularity: Winter semester

Content:

Based on nuclear intrinsic properties the droplet model and the shell model are derived. Radioactive decay laws are discussed. Alpha, beta and gamma decay are introduced phenomenologically and the Gamov theory (alpha) and Fermi theory (beta) are derived. Neutron physics, nuclear reactions, fission, fusion and generation of super heavy elements are treated. Basic physical processes of radiation matter interaction are introduced in order to understand concepts of radiation exposure, dosimetry and radiation measurement techniques. Behavior of radioactive elements in living organisms including man and environment is discussed.

Fundamental Literature:

- Kratz, Lieser *Nuclear and radiochemistry : fundamentals and applications / Vol. 1& 2,* Ausgabe: 3., rev. ed. Weinheim : Wiley-VCH, 2013
- Choppin, Rydberg, Liljenzin, *Radiochemistry and Nuclear Chemistry*, Butterworth Heinemann, Oxford, 1995
- Marmier, Sheldon, *Physics of Nuclei and Particles*, 2 volumes, Academic Press, New York, 1970
- Mayer-Kuckuk, *Kernphysik* (6. Aufl.) Teubner, Stuttgart, 1994
- Knoll, *Radiation detection and measurement*, J. Wiley & Sons, New York, 2000
- Vogt, *Grundzüge des praktischen Strahlenschutzes* 6. Auflage 2011, Hanser Verlag
- http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides
- Strahlenschutzverordnung vom 20. Juli 2001 (BGBl. I S. 1714; 2002 I S. 1459), zuletzt geändert durch Artikel 5 Absatz7 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212)

Recommended knowledge:

- Mechanics / Quantum Mechanics
- Electrodynamics
- Molecules, Nuclei, Particles, Statistics

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Nuclear Energy and Fuel Cycle, Technical Aspects and Public Discourse

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institute for Radioecology and Radiation Protection

Regularity: Winter semester

Content:

In spite of, or maybe even because of, Germany's phase out of nuclear power, this topic is vigorously discussed by politics, stakeholders, NGOs and members of the public. This lecture provides technical basics of the nuclear energy cycle covering uranium mining, fuel fabrication recent and future reactor concepts and the disposal of spent nuclear fuel. Besides the view on technical aspects, the issue is discussed by guest docents of social sciences, ethics and law. You are welcome to articulate your own opinion and discuss with the experts !

Fundamental Literature:

- Streffer, *Radioactive Waste*, Springer
- Michaelis, *Handbuch Kernenergie*
- Heinloth, *Die Energiefrage*, Vieweg
- Additional literature and references will be announced in the lecture

Recommended knowledge:

- Advantageous: Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects" (can be attended in parallel)
- Mechanics / Quantum Mechanics
- Electrodynamics
- Molecules, Nuclei, Particles, Statistics

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Radioactive Contaminations in the Environment and Risk to Human Health

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institute for Radioecology and Radiation Protection

Regularity: Summer semester

Content:

Abundance and migration of natural and anthropogenic radioactivity in the environment are presented. Pathways to man are discussed and risks for humans due to radiation exposure are assessed. The following topics are discussed in detail: Radiation exposure due to the nuclear explosions in Hiroshima and Nagasaki and due to the subsequent decades of nuclear weapons testing. Nuclear accidents of Windscale, Chernobyl, Fukushima, Kystym and criticality accidents. Lost highly radioactive sources (Goiania) . Consequences of uranium mining for workers and environment. Patients exposure due to radium and radon treatments.

Fundamental Literature:

- 🕮 Richard Rhodes, *The making of the Atomic Bomb*
- 🕮 Warner, Kirchmann *Nuclear Test Explosions*
- 🕮 Mosey, *Reactor Accidents Nuclear Engineering* International Special Publications (2006)
- 🕮 Shaw *Radioactivity in the terrestrial environment*, Elsevier, Amsterdam (2007)
- 🕮 Eisenbud, *Environmental Radioactivity*
- 🕮 David Atwood, *Radionuclides in the Environment*, Wiley and Sons, 2010
- 🕮 Further literature announced and provided in the lecture (original papers and web links)

Recommended knowledge:

- Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects"

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Radiation Protection and Radioecology

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institute for Radioecology and Radiation Protection

Regularity: Summer semester

Content:

The lecture comprises ionizing radiation, radioactive decay, interaction of radiation with matter, radiometric measurement techniques, dosimetry, biological effects of radiation, effects of radioactive substances and ionizing radiation on humans, contamination path ways, radioecological modelling of radionuclide migration to humans, natural radiation doses, anthropogenic radiation doses, radiation risk assessment, radiation dose and radiation risk, dose effect curves, collective dose, radiation protection concepts, regulatory dose limits and constraints, radiation protection (emergency) measures, legal regulations, EURATOM basic safety standards

(option to obtain the legal "Knowledge in Radiation Protection" (for radiation protection officers, "Strahlenschutzbeauftragter") for handling unsealed radioactive substances acc. to StrSchV S 4.1)

Fundamental Literature:

- 🕮 Vogt, *Grundzüge des praktischen Strahlenschutzes* 6. Auflage 2011, Hanser Verlag
- 🕮 Siehl, *Umweltradioaktivität*, Ernst & Sohn Verlag Berlin (1996)
- 🕮 Ahrens, Pigeot *Handbook of Epidemiology*, Springer Berlin Heidelberg New York (2205)
- 🕮 *Strahlenschutzverordnung* vom 20. Juli 2001 (BGBl. I S. 1714; 2002 I S. 1459), zuletzt geändert durch Artikel 5 Absatz7 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212)
- 🕮 Allgemeine Verwaltungsvorschrift zu § 47 Strahlenschutzverordnung: *Ermittlung der Strahlenexposition durch die Ableitung radioaktiver Stoffe aus Anlagen oder Einrichtungen* , Drucksache 88/12 15.02.12
- 🕮 Additional literature to be announced in the lecture

Recommended knowledge:

- Prerequisite: Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects"

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Laboratory Course Radiation Protection

Credit hours per week	Credit points (ECTS):	Responsibility:
6	6	Institute for Radioecology and Radiation Protection

Regularity: Winter- and Summer semester

Content:

Experiments on the following topics are conducted:

- Phenomenology of radioactive decay
- Radiation Matter Interaction, inverse square law, radiation attenuation by matter
- Radiometric methods for alpha-, beta- und gamma- radiation
- Characterization of proportional counter and Geiger Müller counter
- Determination of dead time
- Measurement of short lived daughters in the uranium decay series
- Neutron physics, attenuation, radiometric methods (optional MEd, FüBa)
- Neutron activation (optional MEd, FüBa)
- High purity germanium detector
- Dosimetry of radiation exposure
- Measurement of natural radioactivity (optional for MSc, BSc)

Fundamental Literature:

- Skriptum „Radioaktivität und Dosimetrie"
- Kratz, Lieser Nuclear and radiochemistry : fundamentals and applications / Vol. 1& 2, Ausgabe: 3., rev. ed. Weinheim : Wiley-VCH, 2013
- Vogt *Grundzüge des praktischen Strahlenschutzes*, 6. Aufl., Hanser Verlag 2011,
- Choppin, Rydberg, Liljenzin, *Radiochemistry and Nuclear Chemistry*, Butterworth Heinemann, Oxford, 1995
- Marmier, Sheldon, *Physics of Nuclei and Particles*, 2 volumes, Academic Press, New York, 1970
- Mayer-Kuckuk, *Kernphysik* (6. Aufl.) Teubner, Stuttgart, 1994
- Knoll, *Radiation detection and measurement*, J. Wiley & Sons, New York, 2000
- Gilmore, Practical Gamma Ray Spectrometry Wiley, & Sons, New York 2008
- Http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides
- Strahlenschutzverordnung vom 20. Juli 2001 (BGBl. I S. 1714; 2002 I S. 1459), zuletzt geändert durch Artikel 5 Absatz7 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212)

Recommended knowledge:

- Prerequisite: Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects" (can be attended in parallel)

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Nuclear Radioanalytical Techniques

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institute for Radioecology and Radiation Protection

Regularity: Winter semester

Content:

Analytics *of* radioactive substances and analytics *by use of* radioactive substances and ionizing radiation. Measurement of radiation fields, radiation matter interaction, solid state nuclear track detection, alpha, beta, gamma detection, neutron detection, neutron activation, laser based detection and speciation methods, production and characterization of super heavy elements, use of tracer techniques, isotope dilution analysis, nuclear spectrometry, X-ray based analysis techniques, Mossbauer spectroscopy, nuclear magnetic resonance spectroscopy, accelerator mass spectrometry, statistics, characteristic limits, QC and QA, DIN ISO 11929

Fundamental Literature:

- Kratz, Lieser *Nuclear and radiochemistry : fundamentals and applications / Vol. 1& 2*, Ausgabe: 3., rev. ed. Weinheim : Wiley-VCH, 2013
- Vogt, Schultz: *Grundzüge des praktischen Strahlenschutzes*, 6. Aufl., Hanser Verlag München 2011,
- Choppin, Rydberg, Liljenzin, *Radiochemistry and Nuclear Chemistry*, Butterworth Heinemann, Oxford, 1995
- Marmier, Sheldon, *Physics of Nuclei and Particles*, 2 vol-, Academic Press, New York, 1970
- Mayer-Kuckuk, *Kernphysik* (6. Aufl.) Teubner, Stuttgart, 1994
- Knoll, Radiation detection and measurement, J. Wiley & Sons, New York, 2000
- Gordon Gilmore, Practical Gamma Ray Spectrometry Wiley, & Sons, New York 2008
- Http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides
- Strahlenschutzverordnung vom 20. Juli 2001 (BGBl. I S. 1714; 2002 I S. 1459), zuletzt geändert durch Artikel 5 Absatz7 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212)

Recommended knowledge:

- Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects" (can be attended in parallel)

Module Affiliation:
- Modern Aspects of Physics
- Selected Topics of Modern Physics

Nuclear Physics Applications in the Environmental Sciences

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institute for Radioecology and Radiation Protection

Regularity: Summer semester

Content:

Stellar nuclear synthesis processes are derived from basic nuclear physics principles. Formation of the elements in stars and supernova explosions (r- and s-processes) is presented. The concepts of isotopes and physical and chemical isotope effects are introduced. Natural isotope effects and their technical applications are discussed. Use of stable and radioactive tracers and "clocks" in geosphere, atmosphere, hydrosphere, pedosphere and biosphere are treated. Primary, radiogenic, cosmogenic and nucleogenic anomalies of isotope abundances are discussed with respect to their use in age determination: age of the chemical elements, formation of the solar system, and collision history of small extraterrestrial bodies. Environmental element cycles are modelled using simple compartments with special focus on H-3, Be-10, C-14, Cl-36 and I-129. Production of cosmogenic nuclides in the atmosphere and in situ production in the earths surface are explained. Stable and radioactive isotopes in various environmental compartments allow for the investigation of environmental evolution and changes due to anthropogenic influences.

Fundamental Literature:

- Davis, *Meteorites, Comets and Planets*
- Siehl, *Umweltradioaktivität*, Ernst & Sohn Verlag Berlin (1996)
- Oberhummer, *Kerne und Sterne*, Barth Verlagsgesellschaft, Leipzig (1993)
- Choppin, Rydberg, Liljenzin, *Radiochemistry and Nuclear Chemistry*, Butterworth Heinemann, Oxford, 1995
- Marmier, Sheldon, *Physics of Nuclei and Particles*, 2 vol., Academic Press, New York, 1970
- T. Mayer-Kuckuk, *Kernphysik* (6. Aufl.) Teubner, Stuttgart, 1994
- G.F. Knoll, *Radiation detection and measurement*, J. Wiley & Sons, New York, 2000
- Http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides

Recommended knowledge:

- Optics, atom physics, Quantum Phenomena
- Molecules, cores, particles, solid states
- Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects"

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Seminar Radiation Protection and Radioecology

Credit hours per week 2	**Credit points (ECTS):** 3	**Responsibility:** Institute for Radioecology and Radiation Protection

Regularity: Winter- und Summer semester

Content:

To be arranged with the lecturer

Fundamental Literature:

- Will be provided according to topic

Recommended knowledge:

- Lecture "Basics of radioecology and radiation protection: Nuclear Physics and Nuclear Chemistry Aspects"

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Introduction to Particle Physics

Credit hours per week 3+1	**Credit points (ECTS):** 5	**Responsibility:** Institut for Theoretical Physics (Institut für Theoretische Physik)

Regularity: Summer semester

Content:

- Fundamental particles and their interactions
- Symmetries and conservation laws
- Hadrons, quarks, partons
- Quantum chromodynamics
- Electromagnetic and weak interactions and their unification
- the Standard Model of particle physics
- Accelerators and detectors
- Neutrino physics
- Open problems and future projects in particle physics

Fundamental Literature:

📖 F. Halzen und A.D. Martin, *Quarks and Leptons,* Wiley

📖 D.H. Perkins, *Introduction to High Energy Physics*, Cambridge University Press

📖 B.R. Martin and G. Shaw, *Particle Physics,* Wiley

📖 E. Lohrmann, *Hochenergiephysik,* Teubner Verlag

📖 C. Berger, *Elementarteilchenphysik,* Springer

Recommended knowledge:

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics

Electronic Metrology in the Optics Lab

Credit hours per week	Credit points:	Responsibility
2	2	Institute for Gravitational Physics

Is held in: summer semester or winter semester (irregularly)

topics:

- Electronics basics: Kirchhoff's laws, impedance, phasor diagrammes
- Operational amplifiers: function principle and basic circuits
- Resonant circuits and filters (active / passive)
- Spectrum Analyser and Network Analyser
- Measurement und interpretation of transfer functions
- Fundamentals of controls theory
- Photodetection
- Sensors and actuators in optical experiments
- Noise measurements

Basic literature:

- Horowitz & Hill, *The Art of Electronics*, Cambridge University Press
- Abramovici & Chapsky, *Feedback Control Systems*, Kluwer Academic Publishers
- Yariv, *Quantum Electronics*, Wiley
- Primary literature (given in lecture)

Recommended prior knowledge:

- coherent optics

Belongs to module:

- „Selected Topics of Modern Physics“

Foundations of laser medicine and biomedical optic

Regularity	Winter semester		
Responsibility	Alexander Heisterkamp, Holger Lubatschowski		
course	**Foundations of laser medicine and biophotonics**		
Assessment of credit points	**Required performance:** regular participation, participation at the block seminar and excursion **Examination:** oral or written exam at professors choice		
Marking compound	Examination mark		
ECTS: 4 **Weight:** 1	**Attandence study (h):** 45	**Self-study (h):** 30	

Goals:
The students will be introduced to the foundation of laser tissue interaction and they learn to implement the knowledge in clinical relevant application example. In the block seminar and in tutorials (end of semester) they develop and discuss current original article. At the end of the class an excursion to the research lab at the Laser Center Hanover (LZH) and the company Rowiak takes place.

Content:
- Laser systems for the use in medicine and biology
- Ray control system and optical medical equipment
- Optical characteristics of tissue
- Thermal characteristics of tissue
- Photochemical interactions
- Vaporization/coagulation
- Photoablation, opto acoustic
- Photodisruption, nonlinear optics
- Applications in ophthalmology, refractive surgery
- Laser based diagnosis, optical biopsy
- Optical coherence tomography, theragnostics
- Clinical application example

Fundamental Literature:
- Eichler, Seiler: "Lasertechnik in der Medizin." Springer-Verlag
- Berlien: "Applied Laser Medicine"
- Bille, Schlegel: Medizinische Physik. Bd. 2: Medizinische Strahlphysik, Springer
- Welch, van Gemert: "Optical-Thermal Response of Laser-Irradiated Tissue." Plenum Press
- Originalliteratur

Recommended knowledge:
- Coherent Optics

If applicable, admission Prerequisite and a limited number of participants:
Limited number of presentations at the block seminar (20 available places, 5 ECTS), Participation in lecture class and block seminar unlimited (4 ECTS)

Module Affiliation:
- Modern Aspects of Physics

Solid State Lasers

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institute for Quantum Optics

Regularity: Summer semester

Content:

- Solid state laser media
- Optical resonators
- Laser modes of operation
- Diode pumped solid state lasers
- Laser designs: fiber, rod, disc
- Tunable lasers
- Single-frequency lasers
- Ultrashort-pulse lasers
- Frequency conversion

Fundamental Literature:

📖 W. Koechner: Solid-State Laser Engineering
📖 A.E. Siegman: Lasers
📖 O. Svelto: Principles of Lasers

Recommended knowledge:

- Coherent Optics or Nonlinear optics

Module Affiliation:

- Selected Topics of Modern Physics

Optical Coatings

Credit hours per week 2 + 1	**Credits:** 4	**Responsibility** Institute of Quantum Optics (Institut für Quantenoptik)

Regularity: Winter Semester

Content:

- Relevance, functional principle and application areas of optical coatings, present quality level of coating systems for laser technology
- Theoretical basis (compilation of common formulas and phenomena, calculation of coating, systems)
- Production of optical components (substrates, coating materials, deposition processes, control of deposition processes)
- Optics characterization (measurement of transfer properties, losses: total scattering, optical absorption, damage thresholds of optical laser components, non-optical properties)

Fudnamental Literature:

- Will be announced during the lecture
- For an introduction: Macleod, H.A.: Thin Film Optical Filters, Fourth Edition, CRC Press 2010

Recommended knowledge:

- Lectures „Coherent optics“ or. „Nonlinear optics“

Module Affiliation:

- Selected Topics of Modern Physics

Thermodynamics, kinetics and structure of defect semiconductors

Credit hours per week 2	**Credit points (ECTS):** 2	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Winter semester

Content:

The electronical and optical characteristics of semiconductors are multiple determined by defects, they are brought both unintentional (e.g. through crystal growing and processing) or intentional (e.g. as doping). This class deals with thermodynamics, kinetics and structure of defect semiconductors considering especially semiconductor specific problems, concepts and methods. Besides fundamental handling of the relevant concepts this class discuss cross connections to technological applications in photovoltaics, micro- and optoelectronics.

Fundamental Literature:

🕮 to be announced in class

Recommended knowledge:

- Basics of semiconductor physics, e.g. within lecture class Solid State Physics

Module Affiliation:

- Selected Topics of Modern Physics

Simulation and design of solar cells

Credit hours per week 1 + 2	**Credit points (ECTS):** 5	**Responsibility:** Institut for Solid State Physics (Institut für Festkörperphysik)

Regularity: Winter Semester

Description:

- You perform simulations of solar cells by yourself and work for skills to simulate other semiconductor devices.
- You gain fundamental understanding of semiconductor equations, applied physical models and a couple of relevant aspects for numerical simulations.
- You learn how to analyze and optimize semiconductor device on a PC.
- You deepen your understanding of band diagrams, I-V curves, quantum efficiency and other common and frequently used characterization methods in semiconductor physics.

Recommended literatures:

🕮 They will be offered in electronic form.

Prior knowledge:

- Introduction to Solid State Physics.

Module Affiliation:

- Selected Topics of Modern Physics

Knowledge in Radiation Protection (acc. to StrSchV)
(only in German language)

Credit hours per week min. 2	Credit points (ECTS): 2	Responsibility: Institute for Radioecology and Radiation Protection

Regularity: Winter- and Summer semester

Content:

The IRS offers radiation protection courses to attain knowledge in radiation protection (so called "Fachkunde") according to the German radiation protection ordinance, StrSchV, and the German Röntgen ordinance, RöV. Contens are physical basics, dose concepts, biological radiation effects, and technical and organizational concepts of radiation protection.
Each student may chose freely one course from the program offered by IRS (www.strahlenschutzkurse.de). The work load of one course varies between 2 and 6 weekly hours per semester. As an additional qualification the successful completion of the course qualifies to apply for the "knowledge in radiation protection" at the regulator in charge (in Lower Saxony this is the "Gewerbeaufsichtsamt"). For this reason the course is credited with 2 ECTS points irrespective of the actual work load.

Fundamental Literature:

- Vogt, Schultz: *Grundzüge des praktischen Strahlenschutzes*, 6. Aufl., Hanser Verlag München 2011
- Http://www.nucleonica.com/ : Karlsruhe Chart of Nuclides
- *Strahlenschutzverordnung* vom 20. Juli 2001 (BGBl. I S. 1714; 2002 I S. 1459), zuletzt geändert durch Artikel 5 Absatz7 des Gesetzes vom 24. Februar 2012 (BGBl. I S. 212)
- Röntgenverordnung

Recommended knowledge:

- Mechanic and Relativity
- Electricity
- Optics, Atom physics, Qunatum phenomenas
- Molecules, cors, Particals, Solid State

Module Affiliation:

- Modern Aspects of Physics
- Selected Topics of Modern Physics