Description of the degree program

Quantum Technologies in Electrical and Computer Engineering (Master)

PO 1

Date: 11.04.2025

Table of contents

ECTS	120

ECTS	15

Title	Electromagnetic field theory: classical and quantum mechanical applications		
Number	2413000020	**Module version**	
Shorttext		**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Halbleitertechnik
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Tobias Voß
Workload (h)	150		
Class attendance (h)	56	**Self studying (h)**	94
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (120 min) or oral exam (30 min)		
Course achievement			
Module grade composition			

Contents

- vector analysis: repetition and summary
- Potential formalism: scalar potential and vector potential
- Energy considerations, Poynting theorem
- Potentials for the dynamic case, Hertzian dipole
- Field theory in quantum mechanics: electromagnetic interactions in the Schrödinger theory

Objective qualification

After completing the module, students will be able to explain the structure of Maxwell's equations in differential formulation. They will be able to apply the general potential formalism (scalar potential and vector potential) to selected problems in electrostatics. They will be able to describe and analyze the energy flow in dynamic electromagnetic fields. They will be able to justify the Poynting theorem on the basis of Maxwell's theory. They will be able to describe the radiation of electromagnetic fields using the Hertzian dipole model. They can integrate electromagnetic interactions into the Schrödinger equation of quantum mechanics and solve elementary problems in this context.

Literature

D. J. Griffiths: Electrodynamics
J. D. Jackson: Classical Electrodynamics
A. Enders: Electromagnetic Fields (TU Braunschweig)

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Pflichtbereich Grundlagen			

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Electromagnetic field theory: classical and quantum mechanical applications				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Tobias Voß		2,0	Lecture	english

Name of the course				
Electromagnetic field theory: classical and quantum mechanical applications				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Tobias Voß		2,0	Exercise	english

Title	Ambits of Electromagnetic Field Theory		
Number	2419110	**Module version**	
Shorttext	ET-IEMV-11	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Elektromagnetische Verträglichkeit
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Achim Enders
Workload (h)	150		
Class attendance (h)	56	**Self studying (h)**	94
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (120 min) or oral exam (30 min)		
Course achievement			
Module grade composition			

Contents

- Energetic considerations, Poynting theorem, equivalent circuit
- Potentials in the dynamic case, Hertzian dipole and radiation, approximations for the field descriptions
- Analytical calculation methods and examples, numerical field calculation

Objective qualification

The students can explain the structure of the Maxwell equations in differential form, herefrom derive the fully dynamic field solution of the Hertzian dipole and, depending on the special case, give reasons for idealized approximate solutions. By this they can analyze fundamental electrotechnical configurations and abstract to the essential details. They can choose and apply appropriate solution methods for example for energetic problems, Poynting theorem and temporal and spatial variable fields.

Literature

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Pflichtbereich Grundlagen			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Achim Enders Dr. Harald Spieker		2,0	Lecture	german

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Altan Akar Prof. Dr. Achim Enders Lukas Oppermann Dr. Harald Spieker Anne Lena Vaske		2,0	Exercise	german

Title	Advanced Quantum Technology for Engineers		
Number	2413000000	**Module version**	
Shorttext	ET-IHT-0000	**Language**	english
Frequency of offer	only in the winter term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Halbleitertechnik
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Andreas Waag
Workload (h)	150		
Class attendance (h)	56	**Self studying (h)**	94
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (120 min) or oral exam (30 min)		
Course achievement	Presentation (§ 9 APO)		
Module grade composition			

Contents
Objective qualification
Literature
Cohen-Tannoudji, Diu, Laloe 2020, Quantum Mechanics Vol. 1-3, Wiley VCH Leon van Dommelen: Quantum Mechanics for Engineers (2018), pdf available online

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Pflichtbereich Grundlagen			

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Related courses
Rules for the choice of courses
All courses have to be attended
Compulsory attendance

Name of the course				
Advanced Quantum Technology for Engineers				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Stefanie Kroker Prof. Dr. Andreas Waag	Prof. Dr. Andreas Waag	2,0	Lecture	english german
Literature				
Cohen-Tannoudji, Diu, Laloe 2020, Quantum Mechanics Vol. 1-3, Wiley VCH Leon van Dommelen: Quantum Mechanics for Engineers (2018), pdf available online				

Name of the course				
Advanced Quantum Technology for Engineers				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Stefanie Kroker Prof. Dr. Andreas Waag	Prof. Dr. Andreas Waag	2,0	Exercise	english
Literature				
Cohen-Tannoudji, Diu, Laloe 2020, Quantum Mechanics Vol. 1-3, Wiley VCH Leon van Dommelen: Quantum Mechanics for Engineers (2018), pdf available online				

Name of the course				
Advanced Quantum Technology for Engineers				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Stefanie Kroker Prof. Dr. Andreas Waag	Prof. Dr. Andreas Waag	2,0	Seminar	english
Literature				
Cohen-Tannoudji, Diu, Laloe 2020, Quantum Mechanics Vol. 1-3, Wiley VCH Leon van Dommelen: Quantum Mechanics for Engineers (2018), pdf available online				

Title	Introduction to Quantum Information Technology and Quantum Computing		
Number	2413000010	**Module version**	
Shorttext	ET-IHT-0010	**Language**	english
Frequency of offer	only in the winter term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Halbleitertechnik
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Tobias Voß
Workload (h)	150		
Class attendance (h)	56	**Self studying (h)**	94
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (120 min) or oral exam (45 min)		
Course achievement	Presentation (§ 9 APO)		
Module grade composition			

Contents

• QBits: concept and different realizations
• Bloch-Sphere and Q-Sphere
• Basic quantum logic gates: CNOT, Hadamard, …
• Combinations of quantum logic gates and their applications
• Quantum Information and Quantum Communications
• Quantum Cryptography and Quantum Key Distribution
• Quantum Walks and Search Algorithms
• Quantum Simulation
• Quantum Error Correction

Objective qualification

The students can describe different realizations of qbits and can visualize them using the Bloch sphere or the Q-Sphere, respectively. They can apply basic quantum logic gates to form basic applications of qbits (Bell states and others). They can describe basic and advanced models of quantum information processing, transmission, and computing systems. They know the important quantum effects including teleportation, super-dense coding, and no-cloning theorem and can relate them to the quantum algorithms.
From quantum communications, the students know the fundamental results on capacities of quantum-assisted classical, classical-quantum, and pure quantum channels. The students know the current state of the art of multi-user quantum channels and the available rate characterizations.
From quantum computing, the students learn about circuits and operations on qubits and the elements of quantum algorithms, such as Shor’s algorithm, Grover’s algorithm, and quantum random walks. They also understand the corresponding aspects of runtime (lower and upper bounds) and the relation to classical algorithms. The students can present their work to a non-professional audience.

Literature

1. Nielsen, Michael A.; Chuang, Isaac L. (2010). Quantum Computation and Quantum Information (2nd ed.). Cambridge: Cambridge University Press.

2. Cariolaro, Gianfranco. 2015. Quantum Communications. Springer, Cham.
3. Holevo, Alexander S. 2019. Quantum Systems, Channels, Information. De Gruyter.
4. Cohen-Tannoudji, Diu, Laloe 2020, Quantum Mechanics Vol. 1-3, Wiley VCH

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Pflichtbereich Grundlagen			

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Related courses
Rules for the choice of courses
All courses have to be attended
Compulsory attendance

Name of the course				
Introduction to Quantum Information Technology and Quantum Computing				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Christian Deppe Prof. Dr. Tobias Voß	Prof. Dr. Tobias Voß	4,0	Lecture	english
Literature				
1. Nielsen, Michael A.; Chuang, Isaac L. (2010). Quantum Computation and Quantum Information (2nd ed.). Cambridge: Cambridge University Press. 2. Cariolaro, Gianfranco. 2015. Quantum Communications. Springer, Cham. 3. Holevo, Alexander S. 2019. Quantum Systems, Channels, Information. De Gruyter. 4. Cohen-Tannoudji, Diu, Laloe 2020, Quantum Mechanics Vol. 1-3, Wiley VCH				

Name of the course				
Introduction to Quantum Information Technology and Quantum Computing				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Christian Deppe Prof. Dr. Tobias Voß	Prof. Dr. Tobias Voß	4,0	Exercise	english
Literature				
1. Nielsen, Michael A.; Chuang, Isaac L. (2010). Quantum Computation and Quantum Information (2nd ed.). Cambridge: Cambridge University Press. 2. Cariolaro, Gianfranco. 2015. Quantum Communications. Springer, Cham. 3. Holevo, Alexander S. 2019. Quantum Systems, Channels, Information. De Gruyter. 4. Cohen-Tannoudji, Diu, Laloe 2020, Quantum Mechanics Vol. 1-3, Wiley VCH				

Name of the course				
Introduction to Quantum Information Technology and Quantum Computing				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Christian Deppe Prof. Dr. Tobias Voß	Prof. Dr. Tobias Voß	4,0	Seminar	english
Literature				
1. Nielsen, Michael A.; Chuang, Isaac L. (2010). Quantum Computation and Quantum Information (2nd ed.). Cambridge: Cambridge University Press. 2. Cariolaro, Gianfranco. 2015. Quantum Communications. Springer, Cham. 3. Holevo, Alexander S. 2019. Quantum Systems, Channels, Information. De Gruyter. 4. Cohen-Tannoudji, Diu, Laloe 2020, Quantum Mechanics Vol. 1-3, Wiley VCH				

ECTS	20

Title	Nonlinear Photonics		
Number	2415470	**Module version**	
Shorttext	ET-IHF-47	**Language**	english
Frequency of offer	only in the winter term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Hochfrequenztechnik
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Thomas Schneider
Workload (h)	150		
Class attendance (h)	56	**Self studying (h)**	94
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam, 90 minutes, or oral exam, 30 minutes		
Course achievement			
Module grade composition			

Contents

- Basics of linear optics
- 2nd order nonlinear optical effects
- 3rd order nonlinear optical effects
- Nonlinear scattering
- Optical telecommunications
- Nonlinear effects in optical fibers
- Suppression of nonlinear effects
- Applications of nonlinear effects

Objective qualification

After a successful participation, the students know the main basics of nonlinear photonics and will be able to use them for the evaluation of optical systems and optical data transmission systems.

Literature

T. Schneider "#Nonlinear Optics in Telecommunications#", Springer Verlag

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

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Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Thomas Schneider		2,0	Lecture	english

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Arijit Misra Prof. Dr. Thomas Schneider		2,0	Exercise	english

Title	Fundamentals of Nano Optics		
Number	1520430	**Module version**	
Shorttext	PHY-AP-43	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Halbleitertechnik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Stefanie Kroker
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (120 min) or oral exam (30 min)		
Course achievement			
Module grade composition			

Contents

1. Basic concepts (photonic cristals, plasmonics)
2. Production and characterisation (metrology) of nano structures
3. Photonic nano materials / meta materials / meta surfaces
4. Optic nano emitters and nano antennae
5. Active photonic elements

Objective qualification

The participants can describe basic phenomena of light propagation (reflection, scattering, absorption, transmission) at interfaces and in homogeneous media qualitatively and quantitatively.
Participants can name important basic elements of nanooptics, such as waveguides, optical gratings, photonic crystals or metamaterials, discuss their properties qualitatively and name fields of application.
Participants are able to identify the basic elements in complex optical systems and describe their respective functions.
The participants can name important processes of micro- and nanostructuring and explain how they work.
The participants can solve the wave equation in simple dielectric, metallic and hybrid nanooptical systems analytically and semi-analytically and interpret the solutions.
Participants can classify optical resonance phenomena in nanooptical systems and name their essential properties.

Literature

Novotny, Hecht: Principles of nano-optics, Cambridge University Press 2016
Prasad: Nanophotonics, John Wiley & Sons 2004
Jahns, Helfert: Introduction to Micro- and Nanooptics, Wiley VCH 2012

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Stefanie Kroker		2,0	Lecture	english

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Stefanie Kroker		1,0	Exercise	english

Title	Semiconductor Technology		
Number	2413420	**Module version**	
Shorttext	ET-IHT-42	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Halbleitertechnik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Andreas Waag
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam 30 min		
Course achievement			
Module grade composition			

Contents

- physical and chemical basics
- manufacturing of single crystals and wafers
- epitaxial crystal growth processes and crystal defects
- doping processes
- semiconductor measurement technology
- planar technology
- basics of photolithography, deposition processes for dielectrics and etching processes

Objective qualification

After completing the semiconductor technology module, students have:

- an understanding of the basic manufacturing technologies of semiconductors as well as components and integrated circuits made from them.
- the ability to recognize the principles of the most modern manufacturing processes in semiconductor technology and their modes of operation
- the ability to analyze and extrapolate trends in semiconductor technology developments

Literature

- Lecture transparencies
- Script in Englisch (H.-H. Wehmann and A. Schlachetzki)
- Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(Stuttgart, 1998) ISBN: 3-519-06167-8
- Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (Berlin, 1991) ISBN: 3-540-53873-9
- Werner Prost: Technologie der III/V-Halbleiter, Springer (Berlin, 1997) ISBN. 3-540-62804-5
- Ulrich Hilleringmann: Silizium-Halbleitertechnologie, Teubner (Stuttgart, 2004) ISBN: 3-519-30149-0

Remark

Language German or English

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Andreas Waag		2,0	Lecture	english
Literature				
Waldemar von Münch: Einführung in die Halbleitertechnologie; Teubner(1998) Ingolf Ruge, Hermann Mader: Halbleiter-Technologie Springer (1991) Werner Prost: Technologie der III/V-Halbleiter, Springer (1997) Ulrich Hillieringmann: Silizium-Halbleitertechnologie, Teubner (2004) Ausführliches Skript in Englisch Vorlesungsfolien				

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Andreas Waag		1,0	Exercise	english
Literature				
Übungsmaterial wird verteilt.				

Title	Molecular Electronics		
Number	2413600	**Module version**	
Shorttext	ET-IHT-60	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Halbleitertechnik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Tobias Voß
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam (30 min)		
Course achievement	Presentation		
Module grade composition			

Contents

Introduction to molecular electronics
basic considerations (molecular orbitals, conjugated systems)
characterisation tools
transport mechanisms
conductive polymers
optoelectronic applications of molecular systems

Objective qualification

Students are familiar with the fundamentals of organic chemistry. They can explain the structure of molecular orbitals and describe the different hybridization states of carbon atoms in the context of LCAO. They analyze the electron transfer between different molecules in the framework of the Marcus theory and can describe the essential aspects of electronic tunneling processes. They understand the content of current research publications and present them in short presentations. They can describe the structure of conductive polymers, their doping and electronic transport. They analyze the optoelectronic properties of polymers and organic dyes and can classify and explain the relevant electronic excitations and processes.

Literature

Introduction to Nanoscience, S.M. Lindsay, Oxford
Polymer Electronics, M. Geoghegan, G. Hadziioannou, Oxford

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Tobias Voß		2,0	Lecture	english
Literature				
"Molecular Nanoelectronics", M. A. Reed, T. Lee (Eds.), American Scientific Publishers (2003) "Introducing Molecular Electronics", Cuniberti et al. (Eds.), Springer (2005)				

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Tobias Voß		1,0	Exercise	english
Literature				
Vorlesungsfolien, #Übungsunterlagen				

Title	Nanoelectronics		
Number	2411200	**Module version**	
Shorttext	ET-EMG-20	**Language**	
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Oleksandr Dobrovolskiy
Workload (h)	150		
Class attendance (h)	56	**Self studying (h)**	94
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam (30 min), written exam (120 min) only for a high number of participants		
Course achievement			
Module grade composition			

Contents

- Quantum mechanics Wave function, potentials, interaction
- Magnetism
- Superconductivity
- Manufacturing processes
- Josephson junctions
- SET components
- Data memory
- THz transistors
- Quantum computing

Objective qualification

After completing the module ‘Nanoelectronics’, students will have an overview of the fundamentals of quantum mechanics and its application to metallic, magnetic and superconducting components with nanometre dimensions.

Literature

A multi-media CD ROM with script and exercises is availabe for the lecture
- R. Waser, #Nanoelectronics and Information Technology#, Wiley-VCH, 2003, ISBN 978-3527403639
- M. Köhler, #Nanotechnologie#, Wiley-VCH, 2007, ISBN 978-3527318711
- Jasprit Singh, #Modern Physics for Engineers#, Wiley, 1999, ISBN 978-0471330448
- N. Ashcroft, N. Mermin, #Solid State Physics#, Cengage Learning Services, 1976, ISBN 978-0030839931
- S. Flügge, #Rechenmethoden der Quantentheorie#, Springer Verlag 1993, ISBN 978-3540567769
- W. Nolting, #Quantenmechanik#, Band 5 aus #Grundkurs: Theoretische Physik#, Springer-Verlag, 2007, ISBN 978-3540688686

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Oleksandr Dobrovolskiy		2,0	Lecture	german
Literature				
Zur Vorlesung wird eine Multimedia-CD-ROM mit Skript und Übungen angeboten - R. Waser, Nanoelectronics and Information Technology, Wiley-VCH - M. Köhler, Nanotechnologie, Wiley-VCH - Jasprit Singh, Modern Physics for Engineers, Wiley, - N. Ashcroft, N. Mermin, Solid State Physics - S. Flügge, Rechenmethoden der Quantentheorie - W. Nolting, Quantenmechanik, Band 5 aus Grundkurs: Theoretische Physik				

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Oleksandr Dobrovolskiy		1,0	Exercise	german
Literature				
Zur Vorlesung wird eine Multimedia-CD-ROM mit Skript und Übungen angeboten - R. Waser, Nanoelectronics and Information Technology, Wiley-VCH - M. Köhler, Nanotechnologie, Wiley-VCH - Jasprit Singh, Modern Physics for Engineers, Wiley, - N. Ashcroft, N. Mermin, Solid State Physics - S. Flügge, Rechenmethoden der Quantentheorie - W. Nolting, Quantenmechanik, Band 5 aus Grundkurs: Theoretische Physik				

Title	Quantum Structure Devices		
Number	2415310	**Module version**	
Shorttext	ET-IHF-31	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Hochfrequenztechnik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Wolfgang Kowalsky
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (120 min) or oral exam (30 min) or presentation		
Course achievement			
Module grade composition			

Contents

- Schroedinger wave equation
- Potential wells
- Semicondustor materials for quantum structure devices
- Electronical quantum well devices
- Emission and absorption (Einstein relations, Fermi´s golden rule, electron photon interaction)
- Excitons
- Photonic quantum well devices
- Quantum wire and quantum box, one and zero dimensional electronic structures
- Semiconductor devices based on one and zero dimensional quantum strutures
- Tunneling, tunnel diode, resonant tunnel diode

Objective qualification

After completion of the module students have deeper understanding of quantummechanical phenomena in semiconductor devices. They have the ability to design and dimension quantum structures.

Literature

Schiff, Quantum Mechanics, McGraw Hill, ISBN 0070552878

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Reinhard Caspary Prof. Dr. Wolfgang Kowalsky		2,0	Lecture	english
Literature				
- Skript zur Vorlesung - L. I. Schiff, Quantum Mechanics, McGraw Hill				

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Reinhard Caspary Dr. Hans-Hermann Johannes Dr. Lea Könemund Prof. Dr. Wolfgang Kowalsky		1,0	Exercise	english

Title	Measurement Electronics with Experiments		
Number	2411330	**Module version**	
Shorttext	ET-EMG-33	**Language**	english
Frequency of offer	only in the winter term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Elektrische Messtechnik und Grundlagen der Elektrotechnik
Hours per Week / ECTS	6 / 8,0	**Module owner**	Prof. Dr. Meinhard Schilling
Workload (h)	240		
Class attendance (h)	84	**Self studying (h)**	156
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam (30 min), written exam (120 min) only for a high number of participants		
Course achievement	Successful participation in lab work		
Module grade composition			

Contents

Measuring amplifiers with transistors and OPVs
- Electronic switches
- Source circuits
- Measuring transducers
- Analogue filter circuits
- Treatment of interference signals and noise
- Correlation analysis
- Measurement converters (A/D and D/A)
- Measuring device buses
- Time measurement
- Oscilloscopes and trigger circuits

and

carrying out experiments in the following areas
- Electronically controllable switches
- Reference sources for voltages and currents
- Measuring amplifiers
- Analogue-to-digital/digital-to-analogue converters
- Time and frequency measurement
- Oscilloscope
- Correlator

Objective qualification

After completing the module ‘Measurement Electronics with Practice’, students will have an overview of the circuit technology and measurement methods of measurement electronics. The practical knowledge they have acquired enables them to set up circuits for measurement applications. In-depth practical experience with measurement methods

that are dealt with in the measurement electronics lecture is taught in the laboratory. In accordance with the didactic concept of the course and the design of the individual components, interdisciplinary skills are taught and practised. In the context of papers, colloquia and final presentations, these include scientific writing and documentation

Literature

A multi-media CD ROM with script and exercises is availabe for the lecture
- Allan R. Hambley #Electronics#, Prentice Hall, ISBN 978-0136919827
- U. Tietze, Ch. Schenk #Halbleiter-Schaltungstechnik#, Springer-Verlag, 2002, ISBN 978-3540641926
- Dieter Nührmann #Das komplette Werkbuch Elektronik#, Franzis-Verlag, ISBN 978-3772365263
- P. Horowitz #The Art of Electronics#, Cambridge Univ. Press, ISBN 978-0521689175
- Rupert Patzelt, Herbert Schweinzer, #Elektrische Messtechnik#, Springer Verlag 1996, ISBN 978-3211828731

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses

Rules for the choice of courses

Compulsory attendance

Name of the course

Lecturer	Additional lecturers	SWS	Eventtype	Language
Prof. Dr. Meinhard Schilling		2,0	Lecture	german

Literature

Zur Vorlesung wird eine Multimedia-CD-ROM mit Skript und Übungen angeboten - Allan R. Hambley #Electronics#, Prentice Hall, - U. Tietze, Ch. Schenk #Halbleiter-Schaltungstechnik#, Springer-Verlag, 2002 # Dieter Nührmann #Das komplette Werkbuch Elektronik#, Franzis-Verlag - P. Horowitz #The Art of Electronics#, Cambridge Univ. Press - Rupert Patzelt, Herbert Schweinzer, #Elektrische Messtechnik#, Springer Verlag 1996

Name of the course

Lecturer	Additional lecturers	SWS	Eventtype	Language
Prof. Dr. Meinhard Schilling		1,0	Exercise	german

Literature

Zur Vorlesung wird eine Multimedia-CD-ROM mit Skript und Übungen angeboten - Allan R. Hambley #Electronics#, Prentice Hall, - U. Tietze, Ch. Schenk #Halbleiter-Schaltungstechnik#, Springer-Verlag, 2002 - Dieter Nührmann #Das komplette Werkbuch Elektronik#, Franzis-Verlag - P. Horowitz #The Art of Electronics#, Cambridge Univ. Press # Rupert Patzelt, Herbert Schweinzer, #Elektrische Messtechnik#, Springer Verlag 1996

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Frank Ludwig Dr. Thilo Viereck		3,0	Internship	german
Literature				
Praktikumskript auf CD-ROM				

Title	Statistics, Design of Experiments, Optimization		
Number	2415480	**Module version**	
Shorttext	ET-IHF-48	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Hochfrequenztechnik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Wolfgang Kowalsky
Workload (h)	150		
Class attendance (h)	54	**Self studying (h)**	96
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Homework		
Course achievement			
Module grade composition			

Contents

Descriptive and comparative statistics, significance tests, outlier tests, application of important probability distributions (normal distribution, Student#s t-distribution, F distribution). Fundamentals of design of experiments and analysis, statistical analysis of obtained factors and models. Introduction to the matrix version of least squares. System optimization with respect to simple and multiple targets. For all modules (I # III): use of free (for academic purposes) state-of-the-art statistical software R and associated integrated programming environment RStudio.

Objective qualification

Overarching target is to familiarize participants with statistical principles of data analysis, comparison of and inference from experimental data (part I - Statistics), the optimal design of experiments (part II - Design of Experiments), and system optimization (part III - Optimization). Participants will learn to use the state-of-the-art statistical software R and apply the content of the lecture to optimize multi-parameter problems typically encountered in an industrial setting. After attending the course participants will be able to analyze experimental data according to established statistical procedures (test for outliers, confidence intervals for a single response and differences between observations of pairs of responses, evaluation and planning of sample sizes). Part II # Design of Experiments # enables the participants to plan experiments for maximal efficiency and analyze the reliability of the parameters extracted from the data (determination and understanding of the relevance of process variances, confidence intervals and significance of extracted process parameters). Participants furthermore will be skilled in using least-squares methods applied to data analysis and model building. During part III # Optimization # participants will learn to optimize multidimensional systems which include interaction between the controlling factors and multiple, possibly conflicting targets.

Literature

Note: even former editions of the following monographs are well suited for preparation, studies besides, and after the
lecture:
Box, Hunter, Hunter, Statistics for Experimenters: Design, Innovation, and Discovery (Wiley Series in Probability and
Statistics)

Myers, Montgomery, Response Surface Methodology: Process and Product Optimization Using Designed Experiments
(Wiley Series in Probability and Statistics)
Montgomery, Design and Analysis of Experiments (Wiley)
As introduction to R the following free source is recommended as introduction:
https://cran.r-project.org/doc/manuals/r-release/R-intro.pdf

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
		2,0	Lecture	english

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
		1,0	Exercise, small group	english

Title	Electromagnetic Compatibility with Seminar		
Number	2419130	**Module version**	
Shorttext	ET-IEMV-13	**Language**	english
Frequency of offer	only in the winter term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Elektromagnetische Verträglichkeit
Hours per Week / ECTS	5 / 6,0	**Module owner**	Prof. Dr. Achim Enders
Workload (h)	180		
Class attendance (h)	70	**Self studying (h)**	110
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (60 min) or oral exam, presentation of seminar topic		
Course achievement			
Module grade composition			

Contents

- Terms and definitions of EMC
- Sources of interference and disturbance variables, immunity of susceptible devices
- Coupling mechanisms: galvanic, capacitive, inductive coupling, wave and radiation interference
- Establishing of EMC by measures at the sources of interference, at the coupling paths and at the susceptible devices; shielding, overvoltage and overcurrent protection
- Legal basis, product liability, standardization
- EMC test engineering
- Electromagnetic compatibility of biological systems
- Current EMC issues presented in seminar talks

Objective qualification

The students are able to analyze mutual interference and interaction scenarios for electrotechnical and electronic systems and components by emitted interference levels and susceptibilities. The students are able to choose appropriate protection and compatibility measures. The students are able to predict EMC-aspects for the design of facilities and systems at an early stage, as well as to decide on cost-efficient solutions. The students are able to describe the responsibilities for the EMC product safety by the state of standards. The students are able to assess the EMC product safety by failure mechanisms. The students are able to investigate current EMC issues autonomously, structure and present them to an audience.

Literature

- continuously updated script handout
- Joachim Franz, EMV - Störungssicherer Aufbau elektronischer Schaltungen, Teubner, 2002, ISBN 3-519-00397-X
- Clayton R. Paul, Introduction to Electromagnetic Compatibility, Wiley, 2006, ISBN 0-471-75500-1
- Kenneth L. Kaiser, Electromagnetic Compatibility Handbook, CRC Press, 2005, ISBN 0-8493-2087-9

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
You can either choose Electromagnetic Compatibility with Seminar **or** Electromagnetic Compatibility (without seminar). The seminar can also be attened in the summer semester after having attended the EMC lecture.
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Achim Enders Dr. Harald Spieker		2,0	Lecture	german

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Achim Enders Dr. Harald Spieker		2,0	Seminar	english

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Achim Enders Dr. Harald Spieker		1,0	Exercise	german

Title	RF CMOS IC Design with Lab		
Number	2420140	**Module version**	
Shorttext	ET-BST-14	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für CMOS Design
Hours per Week / ECTS	6 / 8,0	**Module owner**	Prof. Dr. Vadim Issakov
Workload (h)	240		
Class attendance (h)	84	**Self studying (h)**	156
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam (30 min)		
Course achievement			
Module grade composition			

Contents
Objective qualification
Literature
Thomas H. Lee " The Design of CMOS Radio-Frequency Integrated Circuits", Cambridge University Press
Remark
For the Master's degree programs in Electrical Engineering, Industrial Engineering Electrical Engineering, and Information Systems Engineering

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Requirements for this module: circuit technology (*Schaltungstechnik*, ST)
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Vadim Issakov		1,0	Exercise	english

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Vadim Issakov		1,0	Internship	english

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Vadim Issakov		2,0	Lecture	english

Title	Applied Quantum Computing: Basics and Devices		
Number	2413620	**Module version**	
Shorttext	ET-IHT-62	**Language**	english
Frequency of offer	only in the winter term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Halbleitertechnik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Stefanie Kroker
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (120 min) or oral exam (30 min), alternativ: homework with final presentation		
Course achievement			
Module grade composition			

Contents

- Basics of Quantum Mechanics
- From Bit to Qubit
- Quantum Circuits I
- Quantum Circuits II
- Entanglement and Teleportation
- Algorithms of Quantum Computing
- Quantum Hardware I
- Quantum Hardware II

Objective qualification

- The students can name the prerequisites for the realization of qubits as well as typical platforms and explain their significance.
- Students will be able to name the strengths and weaknesses of different hardware platforms in common application scenarios and weigh them against each other.
- The students can name the essential process steps for the realization of different quantum computer platforms and to explain challenges that may arise in the manufacturing process.
- Students will be able to use an exemplary platform to explain how selected quantum gates can be realized.

Literature

[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019
[2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010
[3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019
[4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018
[5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Applied Quantum Computing: Basics and Devices				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Stefanie Kroker		2,0	Lecture	german
Literature				
[1] C. Bernhardt: Quantum Computing for everyone (The MIT Press) 2019 [2] M. A. Nielsen & I. L. Chuang: Quantum Computation and Quantum Information (Cambridge University Press) 2010 [3] J. D. Hidary: QuantumComputing: An Applied Approach (Springer) 2019 [4] M. Homeister: Quantum Computing verstehen (Springer Vieweg) 2018 [5] W. Scherer: Mathematics of Quantum Computing (Springer) 2019				

Name of the course				
Applied Quantum Computing: Basics and Devices				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Stefanie Kroker		1,0	Exercise	german

Title	Surface Physics and Experimental Methods		
Number	1520450	**Module version**	
Shorttext	PHY-AP-45	**Language**	english
Frequency of offer	only in the winter term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Angewandte Physik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Uta Schlickum
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam (30 min) or written exam (120 min)		
Course achievement			
Module grade composition			

Contents

Objective qualification

Literature

Ggf. Literatur:
1. Physics at Surfaces, A. Zangwill, Cambridge University Press, 1988
2. Oberflächenphysik des Festkörpers, M. Henzler und W. Göpel, Teubner Studienbücher, 1994
3. Oberflächenphysik, Grundlagen und Methoden, T. Fauster, L. Hammer, K. Heinz, und M.A. Schneider, Oldenbourg Verlag München, 2013
4. Scanning Probe Microscopy and Spectroscopy, R. Wiesendanger, Cambridge University Press, 1994
5. Applied Scanning Probe Methods, B. Bhushan, H. Fuchs, und S. Hosaka, Springer Berlin Heidelberg, 2004

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Title	Experimental Aspects of Quantum Computing		
Number	1511000000	**Module version**	
Shorttext	PHY-IPKM-0000	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Physik der Kondensierten Materie
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Dirk Menzel Prof. Dr. Stefan Süllow
Workload (h)	180		
Class attendance (h)	60	**Self studying (h)**	120
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam (45 min)		
Course achievement			
Module grade composition			

Contents

- superconductivity
- spintronics
- low temperature
- realization of qubits
- charge and spin transport

Objective qualification

The students learn and know the fundamentals in quantum physics for the realization of qubits. They transfer the physical
concepts of superconductivity and spintronics into the context of ‘quantum computing’. They learn possible structuration
methods to represent qubits in real systems and can implement experimental techniques, e. g., charge and spin transport
at low temperature.

Literature

Remark

Students either have to choose "Superconductivity" or "Physical Fundamentals of Spintronics" (lecture + exercise).

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
			Lecture	german

Name of the course				
Physical Fundamentals of Spintronics				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Dirk Menzel		2,0	Lecture	english german

Name of the course				
Physical Fundamentals of Spintronics				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Dirk Menzel		1,0	Exercise	english german

Name of the course				
Superconductivity				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Stefan Süllow		2,0	Lecture	english german

Name of the course				
Superconductivity				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Stefan Süllow		1,0	Exercise	english german

Title	Magnetic Quantum Systems		
Number	1520000000	**Module version**	
Shorttext	PHY-AP-0000	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Angewandte Physik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Dr. Markus Etzkorn
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam (30 min) or written exam (120 min) (based on number of participants)		
Course achievement	Presentation		
Module grade composition			

Contents

Foundations of magnetism
Foundations of magnetic quantum systems
Experimental methods to characterize magnetic quantum systems
Isolated quantum systems and the influence of the environment
Experimental realizations of magnetic quantum systems
Optimization of the properties of magnetic quantum systems
Applications of magnetic quantum systems

Objective qualification

The students comprehend the quantum mechanical foundations of magnetism. They know the theoretical models to describe them and can calculate their static and dynamic properties. The students know the experimental methods to study the properties of magnetic quantum systems as well as the fundamental prerequisites for such studies. They can theoretically describe the fundamental influence of the environment on the properties of magnetic quantum systems. They also know how this can be used to tailor their properties in the desired manner. The students are aware of the most important realizations of magnetic quantum systems, like molecular magnets and defect centers in diamond and have first insights into the current state of research in those areas. They also know some of the applications that magnetic quantum systems are used for. For specific topics on current research they will elaborate seminar presentations with literature research that they will present in a short talk.

Literature

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Magnetic Quantum Systems				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Markus Etzkorn	Dr. Markus Etzkorn		Lecture	english

Name of the course				
Magnetic Quantum Systems				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Markus Etzkorn	Dr. Markus Etzkorn		Seminar	english

Title	Gallium Nitride Technology		
Number	2413000030	**Module version**	
Shorttext		**Language**	english german
Frequency of offer	only in the winter term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Halbleitertechnik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Andreas Waag
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			
Module grade composition			

Contents

The course builds on ‘Lighting Technology I’. While Lighting Technology I focusses on general questions of lighting and lighting technology, this course discusses LED technology and gallium nitride technology in particular:

- Physical principles of LEDs. Band gap engineering in LEDs.
- Semiconductor materials for optoelectronics
- Relationship between material properties and LED properties
- Manufacturing processes
- Efficiency considerations
- Front-end and back-end processing
- Application examples in general lighting, automotive technology, sensor technology
- Infrared LEDs, visible light, UV LEDs

Objective qualification

After completing the module, students will have an overview of the current state of LED technology and the development opportunities that solid state lighting will offer in the future. In addition, they will have a basic understanding of the physical processes within LEDs.

Literature

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Structure Devices			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Gallium Nitride Technology				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Andreas Waag		2,0	Lecture	german

Name of the course				
Gallium Nitride Technology				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Andreas Waag		1,0	Exercise	german

ECTS	20

Title	Information Theory		
Number	2424720	**Module version**	
Shorttext	ET-NT-72	**Language**	english
Frequency of offer	only in the winter term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Nachrichtentechnik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Eduard Jorswieck
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			
Module grade composition			

Contents

- Basics from probability theory
  - Event, probability, random variable, random vector, stochastic process, convergence of random series, convergence theorems
- Basics from information theory
  - Measures for discrete random varaibles: entropy, conditional entropy, relativ entropy, mutual information, conditional mutual information, inequalities
  - Measures for continous random variables: differential entropy, conditional differential entropy, relative entropy, mutual information, inequalities
  - Measure for random series
  - Typical sequences and asymptotic equipartition property
- Source and source coding
  - Definition and properties
  - Source coding for discrete memoryless sources (fixed and variable-length)
  - Selected source codes: Morse, Huffman, Shannon-Fano-Elias
- Data transmission and channel capacity
  - Discrete memoryless channel: channel coding theorem
  - Discrete memoryless channel with state: channel capacities
  - Gaussian channel: model and channel coding theorem
  - Bandlimited Gaussian channel, vector valued channels

Objective qualification

The lecture provides an introduction to the fundamentals of Shannon information theory. The goal is that students can derive the main information theoretic results on maximal achievable lossless (source coding) and lossy (rate distortion theory) compression of data and on maximum data rates for reliable data transmission (channel coding). The methods and tools required, e.g., information measures (entropy, mutual information, capacity etc.) and their properties (typical sequences) will be covered as well as practical applicable simple codes (block, turbo and polar codes).

Literature

#R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.
R.W. Yeung: A First Course in Information Theory, Springer, 2002.
T.M. Cover und J.A. Thomas: Elements of Information Theory, Wiley-Interscience, 2006.
R.G. Gallager: Information Theory and Reliable Communication, Wiley, 1968.
R.G. Gallager: Principles of Digital Communication, Cambridge University Press, 2008.
S. Moser: S. Moser: Information Theory, https://moser-isi.ethz.ch/scripts.html#it

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Karl-Ludwig Besser Prof. Dr. Eduard Jorswieck Martin Le		2,0	Lecture	german
Literature				
- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008. - R.W. Yeung: A First Course in Information Theory, Springer, 2002. - T.M. Cover und J.A. Thomas: Elements of Information Theory, Wiley-Interscience, 2006. - R.G. Gallager: Information Theory and Reliable Communication, Wiley, 1968. - R.G. Gallager: Principles of Digital Communication, Cambridge University Press, 2008. - S. Moser: S. Moser: Information Theory, https://moser-isi.ethz.ch/scripts.html#it				

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Karl-Ludwig Besser Prof. Dr. Eduard Jorswieck Martin Le		1,0	Exercise	german
Literature				
- R.W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008. - R.W. Yeung: A First Course in Information Theory, Springer, 2002. - T.M. Cover und J.A. Thomas: Elements of Information Theory, Wiley-Interscience, 2006. - R.G. Gallager: Information Theory and Reliable Communication, Wiley, 1968. - R.G. Gallager: Principles of Digital Communication, Cambridge University Press, 2008. - S. Moser: S. Moser: Information Theory, https://moser-isi.ethz.ch/scripts.html#it				

Title	Network Information Theory		
Number	2424650	**Module version**	
Shorttext	ET-NT-65	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Nachrichtentechnik
Hours per Week / ECTS	4 / 6,0	**Module owner**	Prof. Dr. Eduard Jorswieck
Workload (h)	180		
Class attendance (h)	56	**Self studying (h)**	124
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (90 min) or oral exam (30 min)		
Course achievement			
Module grade composition			

Contents

- Review point-to-point channel capacity and coding theorem
- Strong typical sequences and their properties
- Multiple-Access Channel: Capacity region compared to TDMA/FDMA/SDMA/NOMA
- #Broadcast Channel: degraded BC capacity region, non-degraded BC achievable rate region and converse
- Interference Channel: very strong, strong, weak interference capacity region, medium interference achievable rate region and converse
- #Relay Channel: achievable schemes amplify-and-forward, decode-and-forward, compress-and-forward, estimate-and-forward #Generalization and application of elements to complex networks

Objective qualification

After completing the lecture, the students will know the building blocks of complex communications networks, i.e., the multiple-access channel, the broadcast channel, the relay channel and the interference channel, their achievable rates and capacity regions including coding and decoding schemes. In addition, the students obtain knowledge to design future wireless and multi-hop as well as ad-hoc networks. They master information-theoretic and mathematical tools to prove coding theorems. They know the state of the art as well as open problems in network information theory.

Literature

#A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011.
D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007.
T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006.
S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004.
R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Pin-Hsun Lin	Dr. Christian Deppe	2,0	Lecture	english
Literature				
A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011 D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007 T. M. Cover and J. A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006 S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004 R. W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008				

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Pin-Hsun Lin	Dr. Christian Deppe	2,0	Exercise	english
Literature				
- A. El Gamal and Y.-H. Kim: Network Information Theory, Cambridge University Press, 2011. - D. Tse and P. Viswanath: Fundamentals of Wireless Communications, Cambridge University Press, 2007. - T.?M. Cover and J.?A. Thomas: Elements of Information Theory, 2nd ed., New York: Wiley-Interscience, Juli 2006. - S. Boyd and L. Vandenberghe: Convex Optimization, Cambridge University Press, 2004. - R.?W. Yeung: Information Theory and Network Coding, Part I, Springer, 2008.				

Title	Coding Theory		
Number	2424420	**Module version**	
Shorttext	ET-NT-42	**Language**	english german
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Nachrichtentechnik
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Thomas Kürner
Workload (h)	150		
Class attendance (h)	56	**Self studying (h)**	94
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam (20 min) or written exam (120 min)		
Course achievement	Colloquium or lab journal		
Module grade composition			

Contents

Objective qualification

Literature

Lecture notes
H.Rohling: Einführung in die Informations- und Codierungstheorie, Teubner
R.Togneri, C.J.S. deSilva: Fundamentals of Information Theory and Coding Design, Chapman&Hall/CRC
H.Schneider-Obermann: Kanalcodierung, Vieweg

Remark

This module is a compulsory module for the major "Communications Engineering".

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Thomas Kürner Michael Schweins		2,0	Lecture	english german
Literature				
Vorlesungsskript H.Rohling: Einführung in die Informations- und Codierungstheorie, Teubner R.Togneri, C.J.S. deSilva: Fundamentals of Information Theory and Coding Design, Chapman&Hall/CRC H.Schneider-Obermann: Kanalcodierung, Vieweg				

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Thomas Kürner Michael Schweins		1,0	Exercise	english german
Literature				
siehe Vorlesung				

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Thomas Kürner Michael Schweins		1,0	Laboratory	english german

Title	Entanglement as a resource for quantum computation and quantum information		
Number	1513000000	**Module version**	
Shorttext	PHY-IMAPH-0000	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Mathematische Physik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Christoph Karrasch Prof. Dr. Patrik Recher Prof. Dr. Andrey Surzhykov
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam (30 min)		
Course achievement	Active participation in tutorial		
Module grade composition			

Contents

Axioms of quantum mechanics, Hilbert space, quantum states
Quantum logic gates and their mathematical representations
Indistinguishable particles, bosons and fermions
Concept of quantum entanglement, EPR paradox, Schmidt decomposition
Bell inequalities: What they are, what they are for and experimental violations
Measurements of entanglement: entropy, concurrence for pure and mixed-states
Quantum teleportation, The no cloning theorem
Shannon’s information theory
Super dense coding and its protocols, Quantum error corrections
Basics of topological quantum

Objective qualification

The students will learn the basics and mathematical descriptions of quantum entanglement both for pure and mixed quantum mechanical states. They will investigate the measures of entanglement and will apply them to particular (two- and many-particle) examples. By making use of the concept of entanglement and of quantum logical gates, the students will learn how to develop and apply quantum teleportation, cryptography and computation protocols.

Literature

Michael A. Nielsen and Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge Univ. Press (2010)
John Preskill, Quantum Compuation and Information (lecture notes Caltech)
Murali Kota, Quantum Entanglement as a resource for Quantum Communication (MIT)

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Christoph Karrasch Prof. Dr. Patrik Recher Prof. Dr. Andrey Surzhykov	Prof. Dr. Christoph Karrasch Prof. Dr. Patrik Recher Prof. Dr. Andrey Surzhykov		Lecture	english
Literature				
Michael A. Nielsen and Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge Univ. Press (2010) John Preskill, Quantum Compuation and Information (lecture notes Caltech) Murali Kota, Quantum Entanglement as a resource for Quantum Communication (MIT)				

Name of the course				
Entanglement as a resource for quantum computation and quantum information				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Christoph Karrasch Prof. Dr. Patrik Recher Prof. Dr. Andrey Surzhykov	Prof. Dr. Christoph Karrasch Prof. Dr. Patrik Recher Prof. Dr. Andrey Surzhykov		Tutorial	english
Literature				
Michael A. Nielsen and Isaac L. Chuang, Quantum Computation and Quantum Information, Cambridge Univ. Press (2010) John Preskill, Quantum Compuation and Information (lecture notes Caltech) Murali Kota, Quantum Entanglement as a resource for Quantum Communication (MIT)				

Title	Topological quantum computing		
Number	1513000010	**Module version**	
Shorttext	PHY-IMAPH-0010	**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Mathematische Physik
Hours per Week / ECTS	3 / 5,0	**Module owner**	Prof. Dr. Christoph Karrasch Prof. Dr. Patrik Recher Prof. Dr. Andrey Surzhykov
Workload (h)	150		
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Oral exam (30 min)		
Course achievement	Active participation in tutorial		
Module grade composition			

Contents

Topology in physics (Chern number, its connection to conductivity, bulk boundary correspondence)
SPT and intrinsic topology: topological models (Su-Schrieffer-Heeger model, toric code, Kitaev (spin) model)
Abelian and non-abelian anyons: what they are and where to find.
Braiding and fusion rules for non-abelian anyons
Quantum circuits and quantum gates
Use of non-abelian anyons for fault-tolerant quantum computing: Ising anyons as an example, parafermions for universal quantum computation

Objective qualification

Understanding exchange statistics (fermions, bosons, anyons), knowledge of topological concepts in condensed matter, being able to apply braiding and fusion rules for non-abelian anyons, get to know topological models, application of concepts of toological quantum computing

Literature

Jiannis K. Pachos “Introduction to Toplogical Quantum Computing”, Cambridge Univ. Press (2012);
Tudor D. Stanescu “Introduction to Topological Quantum Matter & Quantum Computation”, CRC Press

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Topological quantum computing				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Christoph Karrasch Prof. Dr. Patrik Recher Prof. Dr. Andrey Surzhykov	Prof. Dr. Christoph Karrasch Prof. Dr. Patrik Recher Prof. Dr. Andrey Surzhykov		Lecture	english
Literature				
Jiannis K. Pachos “Introduction to Toplogical Quantum Computing”, Cambridge Univ. Press (2012) Tudor D. Stanescu “Introduction to Topological Quantum Matter & Quantum Computation”, CRC Press				

Name of the course				
Topological quantum computing				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Christoph Karrasch Prof. Dr. Patrik Recher Prof. Dr. Andrey Surzhykov	Prof. Dr. Christoph Karrasch Prof. Dr. Patrik Recher Prof. Dr. Andrey Surzhykov		Tutorial	english
Literature				
Jiannis K. Pachos “Introduction to Toplogical Quantum Computing”, Cambridge Univ. Press (2012) Tudor D. Stanescu “Introduction to Topological Quantum Matter & Quantum Computation”, CRC Press				

Title	Quantum Communication Networks		
Number	2424000030	**Module version**	
Shorttext		**Language**	english
Frequency of offer	only in the summer term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	Institut für Nachrichtentechnik
Hours per Week / ECTS	3 / 6,0	**Module owner**	Dr. Christian Deppe
Workload (h)	180		
Class attendance (h)	42	**Self studying (h)**	138
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	Written exam (60 min) or oral exam (30 min)		
Course achievement			
Module grade composition			

Contents

- Introduction to the basic concepts of quantum mechanics and quantum systems
- Introduction to quantum information theory
- Protocols for quantum computation and programming
- Introduction to quantum communication networks
- Capacity calculations for entanglement-assisted communication
- Introduction to communication with the help of quantum repeaters

Objective qualification

The students
- know the basics of quantum communication networks
- understand quantum information theory models
- can calculate rate limits of quantum information-theoretical networks
- understand simple protocols for quantum communication networks
- can simulate simple protocols for quantum communication networks
- can independently develop their own protocols for new models

Literature

Bassoli, R., Boche, H., Deppe, C., Ferrara, R., Fitzek, F. H., Janssen, G., & Saeedinaeeni, S. (2021). Quantum communication networks (Vol. 23, pp. 1-213). Berlin/Heidelberg, Germany: Springer.
Bassoli, R., Boche, H., Deppe, C., Ferrara, R., Fitzek, F. H., Janssen, G., & Saeedinaeeni, S. (2023). *Quantenkommunikationsnetze*, Berlin/Heidelberg, Germany: Springer (2023).

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Quantum Communication Networks				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Christian Deppe	Dr. Christian Deppe	2,0	Lecture	english

Name of the course				
Quantum Communication Networks				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Christian Deppe	Dr. Christian Deppe	1,0	Exercise	english

Title	Software architecture		
Number	4220400	**Module version**	V2
Shorttext	INF-SSE-40	**Language**	
Frequency of offer	only in the winter term	**Teaching unit**	Carl-Friedrich-Gauß-Fakultät
Module duration		**Institution**	
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Ina Schaefer
Workload (h)	150		
Class attendance (h)	56	**Self studying (h)**	94
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	1 graded work: Written exam (90 minutes) or oral exam (30 minutes) or Take-Home-Exam.		
Course achievement			
Module grade composition			

Contents
Objective qualification
Literature
Frank Buschmann u.a. "A System Of Patterns" sowie spezifische Literatur zu einzelnen Kapiteln

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Lukas Linsbauer Kamil Rosiak		2,0	Lecture	english

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Dr. Lukas Linsbauer Kamil Rosiak		2,0	Exercise	english

Title	Online Algorithms		
Number	4227260	**Module version**	V2
Shorttext	INF-ALG-26	**Language**	
Frequency of offer	every 2 years in the summer term	**Teaching unit**	Carl-Friedrich-Gauß-Fakultät
Module duration	1	**Institution**	
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Sandor Fekete
Workload (h)	150		
Class attendance (h)	56	**Self studying (h)**	94
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	graded work: written exam (120 minutes) or oral exam (30 minutes) or Take-Home-Exam. The form of the examination depends on the number of participants and will be announced at the beginnung of the lecture.		
Course achievement	non-graded work: 50% of the exercises must be passed		
Module grade composition			

Contents

- Competitive Analysis
- Self-Organizing Data Structures
- Distributed Paging
- Online Scheduling
- Robot Motion Planning (Exploration, Search)
- Online Packing

Objective qualification

Participants know the necessity and role of algorithms with incomplete information. They can master the most important techniques for analysis and complexity of online algorithms, in particular how to establish upper and lower bounds for competitive factors.

Literature

- Allan Borodin und Ran El-Yaniv. Online Computation and Competitive Analysis. Reissue edition. Cambridge University Press, 2005.

- Amos Fiat und Gerhard Woeginger. Online Algorithms. Springer Verlag, 1998.

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Sandor Fekete		2,0	Lecture	english

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Sandor Fekete		1,0	Exercise	english

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
Prof. Dr. Sandor Fekete		1,0	Exercise, small group	english

Title	Approximation Algorithms		
Number	4227270	**Module version**	
Shorttext	INF-ALG-27	**Language**	
Frequency of offer	every 2 years in the summer term	**Teaching unit**	Carl-Friedrich-Gauß-Fakultät
Module duration	1	**Institution**	
Hours per Week / ECTS	4 / 5,0	**Module owner**	Prof. Dr. Sandor Fekete
Workload (h)	150		
Class attendance (h)	56	**Self studying (h)**	94
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	graded work: written exam (120 minutes) or oral exam (30 minutes) minutes) or Take-Home-Exam. The form of the examination depends on the number of participants and will be announced at the beginnung of the lecture.		
Course achievement	non-graded work: 50% of the exercises must be passed		
Module grade composition			

Contents

- A basic introduction to NP-completeness and approximation
- Approximation for vertex and set cover
- Packing problems
- Tour problems and variations
- Current research problems

In the context of various problems, a wide spectrum of techniques and concepts will be provided.

Objective qualification

Participants know the necessity and role of approximation algorithms. They can master the most important techniques for analysis and complexity of approximation algorithms for designing, including the validity of upper and lower bounds.

Literature

- Vijay V. Vazirani: Approximation Algorithms. 1st edition. Springer Verlag, 2001.

- Dorit Hochbaum: Approximation Algorithms for NP-hard Problems. Course Technology Inc, 1996.

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Title	Mathematical Foundations of Information Theory and Coding Theory		
Number	1294600	**Module version**	V2
Shorttext	MathFoundInfThCodTh	**Language**	
Frequency of offer	only in the winter term	**Teaching unit**	Carl-Friedrich-Gauß-Fakultät
Module duration	1 Semester	**Institution**	
Hours per Week / ECTS	3 / 5,0	**Module owner**	
Workload (h)			
Class attendance (h)	42	**Self studying (h)**	108
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	1 oral exam (20-30 minutes) according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework or presentation according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Module grade composition			

Contents

- Kraft Inequality and McMillan's Theorem
- Huffman Codes
- Stochastic Processes
- Entropy and Entropy Rates
- The Shannon-McMillan-Breiman Theorem
- Universal Codes and the Lempel-Ziv Code
- Rate Allocation

Objective qualification

The students
- understand the of the complex links between their previous mathematical knowledge and the contents of the lecture
- understand the theoretical body of the lecture as a whole and master the corresponding methods
- are able to analyze and apply the methods of the lecture
- understand the applied methods and are able to analyze these
- master the foundations of the field
- are able to them into a larger context

Literature

- Cover & Thomas „Elements of Information Theory“ (Wiley)

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
N.N. Dozent-Mathematik		3,0	Lecture/Exercise	english german

Title	Introduction to Quantum Information Theory		
Number	1294540	**Module version**	V2
Shorttext	IntrQuantInfTH	**Language**	german
Frequency of offer	only in the summer term	**Teaching unit**	Carl-Friedrich-Gauß-Fakultät
Module duration	1	**Institution**	
Hours per Week / ECTS	4 / 6,0	**Module owner**	
Workload (h)			
Class attendance (h)	56	**Self studying (h)**	124
Compulsory requirements			
Recommended requirements	A basic knowledge of classical information theory is recommended		
Expected performance/ Type of examination	graded examination (Prüfungsleistung): 1 written exam (90 minutes) or 1 oral exam (20-30 minutes) according to examiner's specifications. After approval by the examination board mathematics (Prüfungsausschuss Mathematik), the examiner can also choose the take-home exam as the form of examination. The exact examination specifications will be announced at the beginning of the course.		
Course achievement	Non-graded coursework (Studienleistung): Homework according to examiner's specifications. The exact examination specifications will be announced at the beginning of the course.		
Module grade composition			

Contents

- Vectors and Operators,
- States, Observables, Statistics,
- Composite Systems and Entanglement,
- Classical Entropy and Information,
- The Classical-Quantum Channel,
- Quantum Evolutions and Channels,
- Quantum Entropy and Information Quantities

Objective qualification

The students
- understand the of the complex links between their previous mathematical knowledge and the contents of the lecture
- understand the theoretical body of the lecture as a whole and master the corresponding methods
- are able to analyze and apply the methods of the lecture

- acquainted with the basic objects, constructions, and mathematical theorems and their proofs of quantum information theory
- obtain an understanding of the similarities of, and the fundamental differences between, classical information theory and quantum information theory
- learn about applications of quantum information theory in quantum computing and communication.

Literature

- A. Holevo: Quantum Systems, Channels, Information, De Gruyter

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Wahlpflichtbereich Quantum Information Processing and Quantum Computing			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
N.N. Dozent-Mathematik		3,0	Lecture/Exercise	english german

Name of the course				
Lecturer	**Additional lecturers**	**SWS**	**Eventtype**	**Language**
N.N. Dozent-Mathematik		1,0	Exercise, small group	german

ECTS	25

Title	Industrial Internship		
Number	2499040	**Module version**	
Shorttext	ET-STDE-04	**Language**	english german
Frequency of offer	every term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	
Hours per Week / ECTS	8 / 12,0	**Module owner**	
Workload (h)	360		
Class attendance (h)		**Self studying (h)**	
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination			
Course achievement	Final presentation in accordance with the separate regulations "Internship guidelines of the Faculty of Electrical Engineering, Information Technology, Physics" in the version valid at the beginning of the course.		
Module grade composition			

Contents

individual; requirements according to internship guidelines

Objective qualification

The industrial internship provides in-depth preparation for professional life by working directly in an industrial company for at least 10 weeks. Students gain insight into organisational and operational processes and structures as well as into the work methods of engineering activities in industrial companies. Within the wide variety and breadth of structural areas (e.g. research, development, production, sales,...) and fields of activity (e.g. hardware or software development, production planning, quality assurance, sales, (project) management,...) in an industrial company, an exemplary selection with in-depth familiarisation with one or a few of these areas or fields is expected.
The aim of the module is the further development of action patterns and techniques appropriate to the situation and task as well as the further development and adaptation of the methodological skills taught during the course in the engineering solution of technical problems. In addition, students deepen their interdisciplinary knowledge and skills (e.g. discussion and negotiation skills, presentation techniques, documentation, etc.), for example by participating in meetings or by being involved in conceptual, planning or management tasks. They also carry out their own engineering activities (e.g. in conceptual planning, development or quality assurance) independently and represent their own interests. In doing so, they apply the technical knowledge and skills acquired during their studies to practical tasks in an industrial environment.
The activities carried out as part of the industrial internship must be presented in an ungraded presentation. The presentation, including preparation and follow-up work, is worth 3 credits within the 12 credits of this module.

Literature

Remark

The activities carried out as part of the industrial internship must be presented in an ungraded presentation. The presentation, including preparation and follow-up work, is worth 3 credits within the 12 credits of this module. The workload is exclusively at the location of the industrial partner, usually outside the university.

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Überfachliche Qualifikation			

↑

Related courses
Rules for the choice of courses
Compulsory attendance

Title	Professionalisation		
Number	2499560	**Module version**	
Shorttext		**Language**	english
Frequency of offer	every term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	2	**Institution**	
Hours per Week / ECTS	0 / 14,0	**Module owner**	
Workload (h)	420		
Class attendance (h)		**Self studying (h)**	
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	according to the requirements of the course taken from the pool selection		
Course achievement	according to the requirements of the course taken from the pool selection; seminar presentation: presentation according to § 9 APO		
Module grade composition			

Contents

individual

Objective qualification

Key qualifications will be achieved in the following fields:

- Action-oriented courses, scientific cultures
For this purpose, courses from the overall program (pool) of interdisciplinary courses at the Technische Universität Braunschweig are to be selected. The type of examination or coursework and the number of credit points will be announced individually for each module.
https://www.tu-braunschweig.de/studium-lehre/im-studium/lehrveranstaltungen
The Dean of Studies ensures that a list of available courses is published each semester, in which recommendations for particularly practice-oriented courses are given.

- Seminar lecture
Seminar presentation at one of the institutes of the EITP faculty involved in the degree program. An independent examination of a topic with the inclusion and evaluation of relevant literature as well as the presentation and communication of the results in an oral presentation and in a subsequent discussion.

Literature

Assigned to the following degree programs

Degree program	Area	Compulsory form	Semester	ECTS
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Überfachliche Qualifikation			

↑

Related courses
Rules for the choice of courses
A total of 10-14 credits has to be achieved. The seminar presentation of 3 credits is compulsory.
Compulsory attendance

Title	Master's Team Project		
Number	2499520	**Module version**	
Shorttext	ET-STDE-52	**Language**	english
Frequency of offer	every term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	
Hours per Week / ECTS	0 / 8,0	**Module owner**	
Workload (h)	240		
Class attendance (h)	160	**Self studying (h)**	80
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination			
Course achievement	The Master's team project corresponds to the examination requirements of the draft (§ 9 APO). A written project plan must be submitted for the Master's team project at the beginning, which is to be updated during the course of the project. The comparison between initial planning and actual progress must be presented and justified in the final report. The results of the Master's team project must be summarized in a report in which the individual contributions of the project participants are identified. Furthermore, the results must be presented in a presentation (§ 9 APO).		
Module grade composition			

Contents
individual
Objective qualification
The Master's team project is generally completed in groups of at least three students who carry out the design, analysis, construction or simulation of an electrical or information technology system using an overarching topic as an example.
Literature

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Überfachliche Qualifikation			

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Related courses
Rules for the choice of courses
The Master's team project can replace the industrial internship.
Compulsory attendance

ECTS	30

Title	Master's Thesis		
Number	2499510	**Module version**	
Shorttext	ET-STDE-51	**Language**	english
Frequency of offer	every term	**Teaching unit**	Fakultät für Elektrotechnik, Informationstechnik, Physik
Module duration	1	**Institution**	
Hours per Week / ECTS	0 / 30,0	**Module owner**	
Workload (h)	900		
Class attendance (h)		**Self studying (h)**	
Compulsory requirements			
Recommended requirements			
Expected performance/ Type of examination	• Preparation of the Master's thesis (28 credits) • Presentation (according to § 4 para. 14 BPO) (2 credits) The assessment of the presentation is included in the overall grade of the final module with double weighting.		
Course achievement			
Module grade composition			

Contents

individual

Objective qualification

With the successful completion of the final thesis (§ 14 APO) and the presentation, the student demonstrates that he/she is able to work independently on a problem from the chosen subject area using scientific methods within a specified period of time. The qualification objectives of the degree program (Annex 1, § 2 APO) are reflected in the implementation and results of the final thesis with regard to the following components:

- Independent familiarisation with and scientific methodical processing of a topic fundamentally relevant to further development and research in the field of electrical engineering
- Literature research and presentation of the state of the art
- Development of new solution approaches for a scientific problem
- Presentation of the approach and results in the form of a paper
- Presentation of the main results in a comprehensible form
- Consolidation and refinement of key qualifications: management of an own project, presentation techniques and rhetorical skills

Literature

Remark

The Master's thesis is credited with 28 credits and the presentation with 2 credits; the assessment of the presentation is included in the overall grade of the final module with double weighting.

Assigned to the following degree programs				
Degree program	**Area**	**Compulsory form**	**Semester**	**ECTS**
Master Quantum Technologies in Electrical and Computer Engineering PO 1	Abschlussbereich			

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Related courses
Rules for the choice of courses
Compulsory attendance