Coversheet

Examination Regulations for the Master's Degree Program in Optoelectronics and Photonics in the Faculty of Science at Paderborn University

Notice:

This English translation of the Examination Regulations for the Master's Degree Program in Physics is solely provided for the convenience of international students. While care has been taken to ensure that the translation is accurate, only the German version of these Examination Regulations, which has been published in the Official Bulletin of Paderborn University, is legally binding.

On the basis of Section 2 para. 4 and of Section 64 para. 1 of the Higher Education Act of the Region of Nordrhein-Westfalen (Gesetz über die Hochschulen des Landes Nordrhein-Westfalen (Hochschulgesetz – HG)) of September 16, 2014 (GV. NRW. p. 547), Paderborn University has issued the following Examination Regulations:

Contents

I. General

Section 1
Objective and structure of the program, language

(1) The master's examination represents a second final examination and professional qualification for the program in optoelectronics and photonics. Study of the master's degree program in optoelectronics and photonics is intended to teach candidates advanced principles of physics and engineering science and specific knowledge, skills, and methods in the subject area of optoelectronics and photonics. In addition to the general learning objectives of Section 58 paragraph 1 HG, the program of study teaches students to apply and further develop their knowledge of scientific methods from the subject area of optoelectronics and photonics in their work and to act responsibly, taking into account the effects of technological change. Complementing the technical abilities acquired during studies, students also acquire social skills, an awareness of responsibility as a scientist and of the rules of good scientific practice as well as the ability to discuss complex issues and their own research results in the context of current research, and to convey these orally and in writing.

(2) The program consists of a combination of courses (largely in the first year of study) in which the students participate, and practical, research-based sections (largely in the second year of study), which introduce students to independent research work in the subject area of optoelectronics and photonics and provide a targeted education towards optical technologies. In this interdisciplinary study program the students acquire a broad education in the areas of modern optical and information technologies. With a particular focus on practical experience, the study program includes significant amounts of work in the lab as well as hands-on courses in numerical modelling. With a focus on optical technologies the students learn to devise experiments or theoretical/numerical concepts and draw conclusions and utilize the acquired knowledge in the development of novel technological applications and the advancement of science.

(3) The master's examination is intended to determine whether the students have mastered the principles of optoelectronics and photonics in terms of content and have acquired the systematic overview and methodological tools required for independent research work in the field of optoelectronics and photonics and its technological applications.

(4) The master's program, including examinations, is held in English. The regulations of section 6 paragraph 3 and section 17 paragraph remain unaffected.

Section 2
Academic degree

If the master's examination is passed, the Faculty of Science shall award the academic degree of Master of Science (M.Sc.).

Section 3
Commencement of the program

The program commences in the winter semester.

Section 4
Admission requirements

(1) Applicants may be enrolled in the master's program in optoelectronics and photonics only if they have acquired the following:

1. A certificate of university entrance (general or specific to a relevant subject) or, in accordance with a legal ordinance, a certificate of entrance to a university of applied sciences or a certificate of previous educational qualification recognized as equivalent by legal regulation or by the relevant state authority, or satisfaction of the requirements for qualification through professional training or the requirements of the regulations for admission for applicants from abroad (Bildungsausländerhochschulzugangsverordnung).
2. A degree qualification that meets the following requirements:

a) It must be an initial university degree with professional qualification with a normal study period of at least six semesters from Paderborn University or a state or state-recognized university or a state or state-recognized university of cooperative education. Degree qualifications from a foreign state or state-recognized university allow admission provided that the competence acquired does not differ significantly from a degree from Paderborn University as per clause 1. For foreign educational qualifications, the equivalence agreements of the Conference of Education Ministers and the Conference of University Rectors or corresponding statutory regulations shall be observed. Insofar as agreements and conventions of the Federal Republic of Germany with other states about equivalence in the university sector (equivalence agreements) work to the advantage of students of foreign countries notwithstanding clause 2, the regulations of the equivalence agreement shall take precedence. In the event of doubt about the existence or absence of significant differences, the Central Agency for Foreign Education (Zentralstelle für ausländisches Bildungswesen) shall also be consulted. The Examinations Board shall determine compliance with the requirements of clause 2.

b) The degree qualification must include the following competences or there must be no significant differences from them:

aa) Principles of physics: Command of the principles of physics in the areas of solid-state physics, semi-conductor physics and components, electrodynamics, wave optics and principles of spectroscopic procedures, and quantum theory, combined with the ability to create models and abstract mathematical formulations of physical phenomena.

bb) Practicals: Identifying and extracting significant physical interrelationships using experiments conducted by the applicant herself or himself, recording and critically evaluating the results of experiments.

cc) Higher mathematics: Command of the basic mathematical concepts and methods that are required to understand and solve problems in the master's degree in optoelectronics and photonics. This comprises advanced knowledge in the fields of linear algebra, analysis, Fourier series, differential equations, and vector analysis.

The Examinations Board shall determine compliance with these requirements. If requirements are missing, enrolment may take place on the condition that the requirements are made up by appropriate study and passing of associated examinations before registration for the master's thesis. The Examinations Board shall decide on the type and extent of the study and examinations on the basis of the previous degree qualification. Assessments successfully completed outside the degree qualification may also be considered. The missing study which must be made up must not exceed 30 credit points. The study and examinations should be completed in the first semester of the master's degree program.

c) The degree program must have been completed with an overall grade of at least 3.0 (or an equivalent final grade from abroad).

3. An adequate command of English, in accordance with the specifications of para. 2.
4. For a foreign applicant who is not on an equal footing with German applicants as a result or on the basis of state treaties, demonstration of her or his capacity to study by means of the results of a Graduate Record Examination (GRE) Revised General Test. A minimum of 157 points in the "Quantitative Reasoning" section and a minimum of 4.5 points in the "Analytical Writing" section of the GRE Revised General Test are usually required. The Examinations Board may accept a lower points score, depending on the qualification, if the final grade of the qualification in accordance with no. 2 is very good. Applicants with a German university entrance qualification are exempt from demonstrating their ability to study.

(2) Adequate command of the English language shall be demonstrated as follows:

a. A bachelor's degree from an English-speaking country or on an English-language accredited domestic program or
b. Test of English as a Foreign Language (TOEFL) "internet-based" Test (iBT) with a result of at least 80 points or
c. TOEFL "paper-based" test (PBT) with a result of at least 550 points or
d. IELTS test with a result of at least 6.0 or
e. Cambridge Test – First Certificate in English (FCE) or
f. tests of an equivalent level or
g. appropriate previous qualification from school.

(3) Enrollment shall be declined if

1. the admission requirements specified in paragraphs 1 and 2 have not been met,
2. the candidate definitively failed to pass an examination required under the Examination Regulations in the relevant program at a university within the scope of the Basic Law or
3. the candidate definitively failed to pass any other examination required under the Examination Regulations on a program at a university within the scope of the Basic Law if both the failed program is close in content to the master's program in materials science at Paderborn University and the examination that has been definitively failed has significant proximity in terms of content to an examination in a compulsory module on the master's degree program in optoelectronics and photonics at Paderborn University.

Section 5
Normal study period, scope of study, registration for assessments

(1) The normal study period for the master's degree program in optoelectronics and photonics is four semesters (including completion of the examinations). This corresponds to a total workload of 3,600 hours (= 120 credit points) for the students.

(2) The master's program comprises modules with a total of 120 credit points. One credit point, hereafter referred to as CP, corresponds to one ECTS point in accordance with the European Credit Transfer System. One CP corresponds to an average workload of 30 hours.

(3) For every assessment that accompanies a course, separate registration is required via the integrated Campus Management System of Paderborn University. Registration is possible only if the admission requirements have been met. Registration shall be completed within the periods published on the Campus Management System of Paderborn University.

(4) Each course is weighted according to the expected workload required in a cumulative credit point system used to indicate completion of assessments. The average workload is set at 1,800 working

hours per year of study or an average of 900 working hours per semester and is converted to 60 credit points per year of study or an average of 30 credit points per semester.

Section 6
Modularization of the program

(1) Study is modularized in the master's program. Modules normally comprise multiple courses that are linked thematically. The modules are worth 4 to 14 CP (apart from the master's thesis module) and are designed in such a way that they can usually be completed within two semesters.

(2) The program comprises compulsory and elective courses and the General Studies module in the first year of study, with a total of 60 credit points. 42 credit points are for compulsory modules and 6 credit points are allocated to the General Studies module. The first half of the second year of study comprises further compulsory and elective modules and the preparation of an initial piece of research work in the Lab Project module, with a weighting of 14 credit points. The second half of the second year of study is intended for the completion of the master's thesis.

(3) The master's program allows for General Studies worth six credit points, comprising courses outside the subject area of optoelectronics and photonics. Those whose first language is not German are advised to include German courses in their General Studies.

(4) A module usually concludes with a module examination. The credit points indicated in the curriculum and the module description are awarded for successful completion of the module.

(5) The content of the program shall be selected and circumscribed in such a way that it can be completed within the normal study period.

Section 7
Recognition of academic work

(1) Academic work on other programs or on programs at other state or state-recognized universities, at state or state-recognized universities of cooperative education, or on programs at foreign state or state-recognized universities shall be recognized if there is no significant difference in the competences acquired from the academic work that is being replaced. This process does not involve a schematic comparison, but an overall consideration of the purpose of recognition for the continuation of study and completion of examinations. Clauses 1 and 2 apply accordingly to the recognition of academic work completed on state-recognized distance programs or in distance study units developed by the region of Nordrhein-Westfalen in conjunction with the other regions and the Federal Republic as a whole.

(2) The equivalence agreements approved by the Conference of Education Ministers and the Conference of University Rectors and agreements in the context of university partnerships shall be observed in recognizing academic work from foreign universities. Insofar as agreements and conventions of the Federal Republic of Germany with other states about equivalence in the university sector (equivalence agreements) work to the advantage of students of foreign countries notwithstanding paragraph 1, the regulations of the equivalence agreement shall take precedence. In the event of doubt about the existence or absence of significant differences, the Central Agency for Foreign Education (Zentralstelle für ausländisches Bildungswesen) may also be consulted.

(3) On request, the Examinations Board must assign the student to a semester on the basis of recognition in accordance with para. 1.

(4) Applicants who are entitled to start a program on the basis of a classification examination in accordance with Section 49 para. 12 HG shall have the knowledge and skills they demonstrate in the classification examination recognized as completed academic work. The assessments on the certificate for the classification examination are binding for the Examinations Board.

(5) On application, other knowledge and qualifications based on submitted documentation may be recognized by the Examinations Board if that knowledge and those qualifications are equivalent in content and level to the academic work that they are intended to replace.

(6) The Examinations Board is responsible for recognition in accordance with paragraphs 1 and 5. Before determining the existence or absence of significant differences or equivalence, relevant subject representatives shall be consulted. If recognition is refused, the reasons for the decision must be given.

(7) The applicant shall provide the information required (in particular, the knowledge and skills acquired through the academic work and the examination results) for recognition in the form specified by the Examinations Board. The Examinations Board shall decide on applications under paragraph 1 at the latest within ten weeks of full submission of all information required for the decision.

(8) Recognition shall be indicated on the certificate. If academic work is recognized, the grades shall be transferred following conversion as necessary, insofar as the assessment systems are comparable, and included in the respective grade calculation. If no grade is available or if the assessment systems are not comparable, the comment “passed” shall be entered.

(9) A piece of academic work can only be recognized once. This also applies to recognition of other knowledge and qualifications.

Section 8
Examinations Board

(1) For the organization of examinations at Paderborn University and of the tasks assigned by these Examination Regulations, the Faculty Board shall, at the request of the Department of Physics, constitute an Examinations Board to:

1. organize examinations and monitor the way in which they are conducted,
2. ensure compliance with the Examination Regulations and adherence to the procedural regulations agreed for conducting the examinations,
3. decide on inconsistencies in decisions taken in examination procedures,
4. draft an annual report to the Faculty Board, the Dean of Studies, and the Departmental Board on developments in examinations and study periods,
5. carry out any other tasks expressly assigned to the Examinations Board by these Regulations.

In addition, the Examinations Board shall make suggestions for reform of the Examination Regulations and shall publish the distribution of grades. The Chair of the Examinations Board is assigned specific tasks by these Regulations. In addition, the Examinations Board may assign completion of matters that have no fundamental importance to the Chair; this does not apply to decisions about inconsistencies or to the annual report. The Chair shall report to the Examinations Board on decisions made by her or him alone. The Examinations Board and the Chair of the Examinations Board shall be supported by the Examinations Office.

(2) The Examinations Board consists of the Chair, the Deputy Chair, and one further member from the group of lecturing staff, a member from the group of academic assistants, and a student member. At least one of the members from the group of lecturing staff must belong to the Department of Physics and at least one to the Institutes of Electrical Engineering and Information Technology. The members of the Examinations Board are elected by their respective representatives on the Faculty Board according to their groups.

With the exception of the Chair and the Deputy Chair, deputies for the members of the Examinations Board shall be elected accordingly. The period in office of the members from the group of university lecturing staff and from the group of academic assistants is three years; the period in office of the student members is one year. Re-election is permitted. The regulations regarding gender equality pursuant to Section 11c HG must be observed in the composition of the Board.

(3) The Examinations Board is an authority as defined by administrative procedural and administrative process law.

(4) The Examinations Board has a quorum if, in addition to the Chair or the Deputy Chair and one further member of lecturing staff, at least one other member with voting rights is present. The Examinations Board shall make decisions by simple majority. In the event of an equal number of votes being cast, the Chair shall have the casting vote. The student member of the Examinations Board shall not participate in pedagogical-academic decisions, in particular about the evaluation and recognition of academic work; this restriction does not affect the right to act in an advisory capacity.

(5) The Examinations Board is convened by the Chair. The Examinations Board must be convened if at least three of its members so demand.

(6) The meetings of the Examinations Board are not public. The members of the Examinations Board, their deputies, the examiners, and the observers are *ex officio* obliged to maintain confidentiality. If they are not civil servants, they shall be obliged to maintain confidentiality by the Chair of the Examinations Board.

(7) The members of the Examinations Board have the right to attend the examinations when they are being taken.

Section 9
Examiners and observers

(1) The Chair of the Examinations Board shall appoint the examiners and observers. In general, any independent teachers of the courses in which assessments may be taken, in accordance with the specifications of the curriculum and the module descriptions, may be appointed as examiners. The scope of possible examiners may be extended in accordance with the HG. Only those who have at least passed the relevant master's examination or a comparable examination may be appointed as observers.

(2) Examiners are independent in their examination work.

(3) The candidate may propose examiners for the master's thesis and – if several examiners are available to choose from – for the oral examinations. The candidate's proposals shall be accommodated as far as possible. However, there is no legal entitlement.

(4) The Chair of the Examinations Board shall ensure that the candidate is notified of the names of the examiners in good time, usually four, but at least two weeks before the date of the corresponding examination. Announcement on the Campus Management System is sufficient.

Section 10
Failure to appear, withdrawal, unfair practice, breach of regulations, protection provisions

(1) An assessment is deemed to be "non-sufficient/fail" (5.0) if

- the candidate fails to appear at an examination without good reason or

- leaves after the start of the examination without good reason or
- withdraws from the examination after the registration periods specified under paragraph 2 have elapsed without giving good reasons or
- a written assessment is not completed within the specified time.

(2) The candidate may withdraw from an examination for which she or he has registered on the Campus Management System without specifying reasons up to a week before the examination date set via the Campus Management System. The candidate may withdraw from practicals without specifying reasons up to one week before the first experiment via the campus management system.

(3) After the period specified under paragraph 2, the reasons asserted for the failure to appear at or withdrawal from the examination must be immediately made known by the candidate to the Examinations Board to its satisfaction, and at the latest five working days from the respective examination date. In the event of illness of the candidate, a medical certificate dated on the day of the examination at the latest confirming incapacity to take the examination is sufficient. If there is sufficient factual evidence to suggest that incapacity to complete the examination is likely or other evidence that appears to be relevant, a medical certificate from a medical officer of Paderborn University may be demanded at the cost of the University. The medically certified illness of a child, as defined under Section 25 paragraph 5 of the German Federal Education and Training Assistance Act, constitutes incapacity of the candidate to take the examination if alternative arrangements for childcare cannot be made, in particular if parental care is provided mainly by the candidate alone. If the Examinations Board accepts the reasons, the candidate shall be notified in writing and a new examination date shall be set. If the Examinations Board does not accept the reasons, the candidate shall be notified in writing. The examination results already available shall count if the reasons are accepted.

(4) If a candidate engages in unfair practice or attempts to engage in unfair practice, the examination concerned is deemed to have been given the grade “non-sufficient/fail” (5.0). If a candidate uses an unauthorized aid, the assessment concerned may be given the grade “non-sufficient/fail” (5.0). The incidents shall be recorded by the supervisors concerned. The determination pursuant to clause 1 or the decision pursuant to clause 2 shall be made by the respective examiner.

(5) A candidate who disrupts the orderly course of the examination may be excluded from continuing to sit the examination, usually following a warning, by the respective examiners or supervisors; in this case, the assessment is deemed to have been given the grade “non-sufficient/fail” (5.0). The reasons for the exclusion shall be recorded.

(6) The candidate may demand within 14 days that decisions under paragraph 4 or paragraph 5 be reviewed by the Examinations Board. The candidate shall be notified of negative decisions immediately in writing by the Examinations Board and provided with the reasons and with information about legal remedies. Before the decision is made, the candidate shall be given the right to be heard.

(7) In serious cases, the Examinations Board may exclude the candidate from taking further assessments. Unfair practice may also incur a financial penalty of up to €50,000 in accordance with Section 63 para. 5 HG and lead to exmatriculation (removal from the register of students).

(8) The Examinations Board shall also decide on compensation for disadvantages for students with a disability or chronic illness. If, as a result of their disability or chronic illness, the student is not in a position to complete assessments in whole or in part using the intended methods, compensation for the disadvantage shall be granted. Compensation for disadvantage to be considered includes taking organizational measures or providing organizational aids, extending deadlines, or offering a different, equivalent form of assessment. Evidence of disability or chronic illness must be provided. A medical report or psychological assessment may be required for this purpose. The application shall specify and justify the modifications requested. At the request of the student or of the Examinations Board in agreement with the student, the Officer for Students with Disabilities or Chronic Illnesses may provide recommendations for the form of compensation for disadvantage.

(9) Account shall be given to the particular situation of students with family obligations when studying and completing assessments. This can be done in the following ways, among others:

a) At the request of a candidate, the protective provisions pursuant to Sections 3, 4, 6 and 8 of the German Maternity Protection Act (MSchG) shall be observed as appropriate. The necessary evidence shall be attached to the application. The Examinations Board may decide on alternative forms of assessment, taking the individual case into account. The maternity protection periods shall interrupt all periods specified by these Examination Regulations; the duration of the maternity protection shall not be included in the period concerned.

b) Similarly, the periods of parental leave in accordance with the applicable German Federal Parental Benefit and Parental Leave Act (BEEFG) shall be observed on request. The candidate shall notify the Examinations Board in writing, attaching the necessary evidence, of the period or periods for which she or he wishes to take parental leave at the latest four weeks before the time from which she or he wishes to take parental leave. The Examinations Board shall check that the statutory requirements which would trigger a right to parental leave for an employee under the Federal Parental Benefit and Parental Leave Act have been met and shall set the deadlines and periods in accordance with the individual case. The submission period for the master's thesis may be extended to a maximum of twice the intended completion period. Otherwise, the thesis is deemed not to have been assigned and the candidate shall be given a new topic upon expiry of the parental leave.

c) On request, the Examinations Board shall take account of absences resulting from the care and upbringing of children as defined by Section 25 para. 5 of the Federal Education and Training Support Act and absences for the care of a spouse, registered civil partner, or partner in a cohabitation relationship, or of an immediate relative or immediate in-law, and shall set periods and deadlines in accordance with the individual case. Clauses 4 and 5 of letter b) also apply accordingly.

II. Master's examination

Section 11
Type and scope of the master's examination

(1) The master's examination consists of assessments that are completed on the master's degree program in optoelectronics and photonics, the master's thesis (25 CP), and an oral defense (5 CP). The master's examination consists of the following module examinations associated with the program of study:

a. Compulsory module *Circuit and System Design* from the module group *Fundamentals of Optoelectronics* with 6 credit points.
b. Compulsory module *Modelling and Simulation* from the module group *Fundamentals of Optoelectronics* with 6 credit points.
c. Compulsory module *Optoelectronic Semiconductor Devices* from the module group *Core Subjects I* with 6 credit points.
d. Compulsory module *Computational Optoelectronics and Photonics* from the module group *Core Subjects I* with 6 credit points.
e. Compulsory module *Fields and Waves* from the module group *Core Subjects II* with 6 credit points.
f. Compulsory module *Quantum Electronics* from the module group *Core Subjects II* with 6 credit points.
g. Compulsory module *Lab Courses* with 6 credit points. A total of four laboratory experiments from the range available shall be chosen and completed successfully within this module.
h. Four elective modules from the module group *Specialization* with 6 credit points each.

i. Compulsory module *Topics in Optoelectronics and Photonics* with 4 credit points.
j. The *Lab Project* module with 14 credit points, as a program-related project for half the year.
k. The *Master's Thesis* module with 30 credit points.

(2) In the General Studies module, courses worth 6 credit points shall be completed by certified participation.

(3) The module descriptions for the elective modules are attached to the Examination Regulations.

Section 12
Admission to examinations

(1) Only those who are enrolled in the master's degree program in optoelectronics and photonics at Paderborn University or are registered as visiting students in accordance with Section 52 paragraph 1 or Section 2 HG may be admitted to examinations for the master's degree program in Optoelectronics and Photonics. These requirements must also be observed during the examinations.

(2) In accordance with available capacity and on application to the Examinations Board, in addition to paragraph 1, students on the bachelor's degree program in Physics and the bachelor's degree program in Electrical Engineering who have acquired at least 152 credit points relevant to their graduation and who are likely to meet the admission requirements for the master's degree program may be admitted to modules on the master's degree program worth a maximum of 30 credit points for one semester. Use may be made of this regulation once only. Repetition of a failed master's examination taken in advance is only possible after enrollment in the master's degree program. Students do not have a right to be admitted to the master's degree program at a later date.

(3) Only those who have successfully completed the Lab Project module, have achieved at least 74 CP and, in the case of conditional enrolment pursuant to Section 4, have passed the relevant examinations can be admitted to the master's thesis.

(4) Registration for admission to the master's thesis shall be submitted in writing to the Chair of the Examinations Board via the Examinations Office. The following must be attached to the registration: evidence of compliance with the admission requirements specified in paragraphs 1 and 3

(5) Admission of the master's thesis shall be refused if the requirements specified in paragraphs 3 and 4 are not met.

(6) Further requirements for participation in examinations may be stipulated in the module descriptions.

Section 13
Completion of a module

With the exception of the General Studies module, every module in the master's program is concluded with a module examination. This module examination shall take place in temporal proximity to the module. A module examination usually takes the form of an examination at the end of the module (final module examination). However, the module examination can also take place in the course of the module (in particular, in temporal proximity to a course) or consist of several partial examinations (partial module examinations). If the module examination consists of several partial module examinations, each partial module examination must be passed. The module grade corresponds to the grade achieved in the module examination. Credit points may be acquired only if the module has been completed in full. A module is completed successfully when the final module examination or partial module examinations have been passed with a minimum grade of "sufficient." The General Studies module has been completed successfully when certified participation has been demonstrated.

Section 14
Forms of assessment in the modules and certified participation

(1) Assessments may take the form of written examinations, oral examinations, written homework followed by a presentation, or other forms. The precise allocation of individual assessments is indicated in the module descriptions in the Appendix. With the exception of oral examinations, students shall usually be notified of their grade on the Campus Management System of Paderborn University at the latest six weeks after the assessment has been completed.

(2) A distinction is made between the following types of assessment:

a) Written examinations

In written examinations, the candidate is expected to demonstrate that she or he is able to identify problems in the subject area in a specified time using resources permitted by the examiner and to solve them using standard methods.

Written examinations are usually graded by one examiner. A final attempt at the examination shall be graded by two examiners.

The duration of a written examination is indicated in the module descriptions. Written examinations using the multiple choice system are not permitted. The examiner shall determine which resources may be used in a written examination. A list of approved resources shall be announced with the date of the examination.

b) Oral examinations

In the oral examinations, the candidate is expected to demonstrate that she or he can recognize the interrelationships within the examination area and can classify specific questions in this context. Oral examinations are also intended to establish whether the candidate has a broad basic knowledge.

Oral examinations shall be held in front of at least two examiners (examination before a panel) or in front of one examiner in the presence of a knowledgeable observer, as group or individual examinations. Simultaneous examination of up to four candidates is permitted. Before determining the grade, the examiner shall listen to the views of the other examiners on the panel or the observer without the candidate being present. A final attempt at an examination shall be graded by two examiners.

The duration of oral examinations is indicated in the module descriptions. In the case of group examinations, the overall duration of the examination shall be extended accordingly.

The key points and results of the examination shall be recorded in a report. The candidate shall be notified of the result by the examiner following the oral examination.

Students who want to take the same examination at a later examination date shall be admitted to listen to the examination if space permits and provided that there is no objection from a candidate. Admission does not include advice or notification of the result of the examination to the candidate.

c) Written report followed by a presentation

Written reports are written analyses of a topic developed independently in the subject area of a seminar. The topic of the written report is described in an oral presentation (approx. 25 minutes) to the students in the seminar. A grade will be awarded for the assessment of written homework with subsequent presentation.

The examiners shall follow the same regulations as for the grading of written and oral examinations.

d) Seminar papers

A seminar paper is a presentation of approximately 30 minutes duration on the basis of a written analysis (about ten pages in length). Students are expected to demonstrate that they are capable of scientific analysis of a topic and that they are able to present the results.

e) Assessments of practicals

Assessment of practicals consists of a prescribed number of experiments from a structured catalogue of experiments. An experiment comprises preparation (including research of the literature), execution (including reflections on comments of the supervisor), written analysis (in particular the practical report, including research of the literature), presentation, and discussion of the written analysis.

In the practicals, candidates are expected to demonstrate that they can prepare an experimental task appropriately, conduct it while taking safety aspects into account, evaluate, and document it. In order to practice collaboration and in the interests of safety, experiments are usually conducted in small groups of two to four students. Participation in practical meetings is compulsory.

Before each experiment begins, the supervisor shall verify that the students' preparation is adequate to conduct the experiment successfully and safely. If this is not the case, the experiment can only be carried out at a later date.

While the experiment is being conducted, an original measurement report is recorded and signed off by the supervisor.

A new experiment usually cannot be started until the analysis of the previous experiment has been submitted.

Deficiencies in the analysis and presentation can be improved within a further week.

(3) Certified participation is confirmed when the work completed indicates that there has been more than superficial engagement with the subjects underlying a task.

Section 15
Assessment in the modules

(1) Assessments are completed in the master's program in accordance with the specifications of the module descriptions. The grades from the module examinations go towards the final grade for the master's examination. They are weighted according to the credit points achieved.

(2) If the module descriptions include overall guidelines as to the form and/or duration/extent of assessments, the Examinations Board shall define in consultation with the examiner how, specifically, the assessment is to be completed. In all courses, confirmation of how the assessment is to be completed shall be given at the latest in the third week from the start of teaching by the teacher concerned. This applies accordingly to evidence of certified participation. Assessments are related to the content and skills acquired in the associated courses.

(3) Students who are more than one semester behind in completing their subject examinations for a section of the program are strongly recommended to attend an advisory meeting.

Section 16
Grading of assessments in the modules

(1) The grades for the individual assessments are determined by the respective examiners. The following grades shall be used for assessment:

1= very good	= an outstanding performance;
2 = good	= a performance significantly above the average requirements;
3 = satisfactory	= a performance that meets the average requirements;
4 = sufficient	= a performance which, despite its defects, still satisfies the requirements;
5 = non-sufficient/fail	= a performance which no longer satisfies the requirements because of serious deficiencies.

(2) For more differentiated grading, intermediate grades can be created by raising or lowering the individual grade by 0.3. The intermediate grades 0.7, 4.3, 4.7, and 5.3 are not permitted.

(3) If a module grade is made up of several grades together, the arithmetic mean shall be taken, weighted according to the workload of the associated course. The result shall be accurate to one decimal place. The grades are:

for an average up to 1.5	=	very good
for an average of 1.6 to 2.5	=	good
for an average of 2.6 to 3.5	=	satisfactory
for an average of 3.6 to 4.0	=	sufficient
for an average over 4.0	=	non-sufficient/fail

(4) If an examination is graded by several examiners and the results vary, the grade shall be determined by the arithmetic mean of the grades of all examiners. Otherwise, paragraph 3 applies accordingly.

(5) Academic performances are graded “pass” or “fail.”

(6) Evidence of certified participation shall be provided.

Section 17
Master’s thesis

(1) The master’s thesis is used to acquire research-related skills based on a specific research project. In this research phase, the student is expected to show that she or he is able to work independently on a research task from the subject area of optoelectronics and photonics, to describe the task, the method used for solving it and the solution comprehensibly, and to interpret it appropriately. This research phase is a significant part of scientific training. It is worth 25 credit points. The master’s thesis is written in English. It may be written in another language on request. Where necessary, this decision will be taken by the Examinations Board when the topic is assigned.

(2) The topic for the master’s thesis may be assigned and supervised by professors, junior professors, private and university tutors, academic assistants with Habilitation, assistants with Habilitation and heads of junior research groups, provided that they are involved in research and teaching in the Department of Optoelectronics and Photonics at Paderborn University. The master’s thesis may also be completed outside Paderborn University if the topic is assigned and supervised by an individual from the group of persons listed in clause 1. University lecturers or examiners authorized in accordance with Section 65 paragraph 1 HG with Habilitation who are involved in research and teaching at Paderborn University outside the area of optoelectronics and photonics may also assign and supervise topics for the master’s thesis. The individual who assigns the topic and the supervisor shall be appointed by the Chair of the Examinations Board.

(3) The candidate has the right to propose the person who assigns the topic and the topic itself. This does not justify any legal claim.

(4) The candidate shall attempt to arrange a topic for the master’s thesis herself or himself. On application, the Chair of the Examinations Board shall ensure that the candidate is given a topic for the master’s thesis in good time. The Examinations Office shall record the time at which the topic is assigned.

(5) The completion time for the master’s thesis is five months. Topic, question, and scope of the master’s thesis shall be circumscribed in such a way that it can be completed within the framework of the intended workload of 25 CP (approx. 750 hours). In individual cases, the Examinations Board may exceptionally extend the completion period by up to eight weeks on justified application by the candidate, if the reasons relate to the topic of the thesis and the supervisor pursuant to paragraph 2 agrees.

(6) If the candidate falls ill during the completion time, she or he may apply for an extension to the submission deadline for the master’s thesis of a maximum of four weeks. Immediate submission of a

medical certificate is essential in this case. A medical certificate confirming incapacity to take the examination is sufficient. If there is sufficient factual evidence to suggest that incapacity to complete the examination is likely or other evidence that appears to be relevant, a medical certificate from a medical officer of Paderborn University may be demanded at the cost of the University. If the Examinations Board accepts the application, the candidate shall be notified in writing. The extension shall correspond to the period of illness; it does not entail an extension of the normal study period. If the period of the illness exceeds four weeks, the candidate may, at her or his discretion, complete the thesis within the deadline extended by four weeks or apply for a new topic. If the Examinations Board rejects the application, the candidate shall likewise be notified in writing.

(7) The topic for the master's thesis may be returned only once and within the first four weeks from assignment.

(8) On submission of the master's thesis, the candidate shall confirm in writing that she or he has written the dissertation herself or himself and has cited or specified the sources and resources used. The length of the master's thesis shall be appropriate to the subject covered, with the aim of maximum concision. The thesis shall not exceed 80 pages (without appendices).

(9) The master's thesis, including extracts thereof, must not have been prepared for another examination in the same program or any other program.

Section 18
Submission and grading of the master's thesis

(1) Two copies of the master's thesis shall be submitted on time to the Central Examinations Office; the time of submission shall be recorded. If the thesis is submitted by post, the time of submission to the post office (postmark) is definitive. If the master's thesis is not submitted on time, it shall be graded "non-sufficient/fail" (5.0).

(2) The master's thesis shall be assessed and graded by two examiners. At least one of these shall be a teacher in the Department of Optoelectronics and Photonics. Only one of the examiners may be a junior research group leader. One of the examiners shall be the supervisor, while the second examiner shall be appointed by the Chair of the Examinations Board from the group of persons specified in Section 17 paragraph 2 clauses 1 and 3.

The individual grading shall be carried out in accordance with Section 16 and shall be justified in writing. The grade for the thesis shall be determined by the arithmetic mean of the individual grades in accordance with Section 16, provided that the difference is not greater than 2.0 and the grades for the individual assessments are a minimum of "sufficient." If the difference is greater than 2.0 or one of the grades is "non-sufficient/fail" while the other is "sufficient" or better, a third examiner shall be appointed by the Chair of the Examinations Board to assess the master's thesis. In this case, the grade for the thesis shall be determined by the arithmetic mean of the three grades. However, the thesis may only be assessed as "sufficient" or better if at least two of the grades are "sufficient" or better. Otherwise, the master's thesis is deemed to have been failed. The grade for the thesis goes into the overall grade for the master's thesis with a weighting factor of 5.

(3) The student shall be notified of the grade for the master's thesis at the latest four weeks after submission on the Campus Management System of Paderborn University.

Section 19
Oral defense of the master's thesis

(1) At the latest six weeks after submission of the thesis, an oral defense of the master's thesis shall be held, followed by an assessed discussion of the topic of the written master's thesis and its results (referred to together in subsequent paragraphs of the Regulations as "oral defense"). The oral defense, including the assessed discussion, shall last a minimum of 30 minutes and a maximum of 45 minutes. 5 CP are awarded for the defense.

(2) During the oral defense of the master's thesis, the candidate shall briefly present and explain its main themes and findings. In the following assessed discussion, the candidate is expected to demonstrate a fundamental understanding of relevant interrelationships in physics and engineering science in direct relation to the completed thesis and in the narrow context of the completed thesis' content.

(3) The oral defense of the master's thesis, including the assessed discussion, shall take place in front of two examiners, who are usually identical to the assessors of the master's thesis pursuant to Section 18 para. 2. If the grades deviate from one another, the grade shall be determined by the arithmetic mean of the two individual grades. The oral defense and assessed discussion shall be graded together and contribute to the overall grade for the master's thesis module with a weighting factor of 1.

(4) The key points and results of the oral defense and assessed discussion shall be recorded in a report. The candidate shall be notified of the result by the examiners following the oral defense.

(5) If the assessment of the oral defense with following assessed discussion is unsatisfactory, it may be repeated once. If the oral defense and assessed discussion is failed definitively, the master's thesis is also deemed to have been failed. In this case, Section 21 paras. 4 and 5 apply.

Section 20
Additional modules

In addition to the courses required for the degree program, students may complete further modules beyond those required for the master's examination (additional modules). The module grades achieved in additional modules shall be listed on the Transcript of Records unless the student requests otherwise. They shall not be taken into account in determining the overall grade for the master's examination. The additional modules shall be marked as such on enrollment.

Section 21
Retaking assessments

(1) A final module examination or partial module examination that has been passed can neither be retaken nor improved.

(2) A final module examination or partial module examination that has been failed can be retaken three times.

(3) A module is definitively failed if the final module examination or a partial module examination cannot be retaken again.

(4) The master's thesis may be retaken once if it is given the grade "non-sufficient/fail". A new topic must be set in this case. In the case of a retake of the master's thesis, a return of the topic within the period specified in Section 17 paragraph 6 is only permitted, however, if the option to return the topic was not exercised in the first attempt.

(5) The master's thesis and its oral defense shall normally be retaken in the next semester.

(6) If the assessment of the oral defense is non-sufficient/fail, it may be repeated once. If it is failed definitively, the master's thesis is also deemed to have been failed. In this case, Section 21 paragraphs 4 and 5 apply.

(7) If the oral defense of the master's thesis is not passed, the Examinations Board shall set a date for the retake in consultation with the candidate. This shall be in the course of the following eight weeks. The Examinations Board shall decide on legitimate exceptions.

(8) Courses that form part of the General Studies module may usually be repeated without restriction.

Section 22
Assessment of the master's examination and determination of overall grade

(1) The master's examination has been passed when all module examinations, the master's thesis, and the oral defense have received a minimum grade of "sufficient" (4.0). The requirements for successful completion of the program are specified in Section 23.

(2) The overall grade is determined by weighting the module grades and the overall grade for the master's thesis according to credit points and calculating the arithmetic mean. In calculating the result, only the first decimal place shall be taken into consideration; all other decimal places shall be deleted without rounding.

The grades are:

for an average	up to and including 1.5 = very good
for an average	over 1.5 up to and including 2.5 = good
for an average	over 2.5 up to and including 3.5 = satisfactory
for an average	over 3.5 up to and including 4.0 = sufficient
for an average	over 4.0 up to 5.0 = non-sufficient/fail

(3) The overall grade "very good" shall be replaced with "passed with distinction" if the overall grade for the master's thesis is 1.0 and the weighted average corresponding to paragraph 2 for the remaining assessments is 1.3 or better.

Section 23
Successful completion of the program, definitive failure

(1) The program has been successfully completed when the master's examination has been passed and all modules have been completed successfully. The master's examination has been passed when all module examinations, the master's thesis, and the oral defense have received a minimum grade of "sufficient" (4.0).

(2) The master's examination has been failed definitively if

1. a module has been failed definitively

   or

2. the master's thesis cannot be repeated again

(3) The decision of a definitive failure of the master's examination shall be given to the candidate in written form by the Chair of the Examinations Board. The decision shall be communicated with information about possible legal remedies.

(4) If a candidate has definitively failed the master's examination, on request she or he shall be issued with a transcript which includes the assessments completed and any credit points (ECTS credits) awarded, and which indicates that the Masters examination has been failed definitively. On request, students who withdraw from the University for other reasons without graduating shall be issued with a

transcript following exmatriculation, which includes the assessments completed and any credit points (ECTS credits) awarded.

Section 24
Certificate, Transcript of Records, Diploma Supplement

(1) If the candidate has successfully completed the program, she or he shall receive a certificate confirming the result. This certificate shall include the name of the program, the normal study period, and the overall grade. The certificate shall indicate the date on which the last assessment was completed. It shall also show the date on which it was issued. The certificate shall be signed by the Chair of the Examinations Board.

(2) In addition, the candidate shall receive a Transcript of Records in which all of the assessments completed and the study period are listed. The Transcript of Records includes details of the credit points (ECTS credits) and the grades achieved for the completed modules and for the master's thesis. It also includes the topic of the master's thesis and the overall grade achieved for the master's examination.

(3) With the final certificate, the graduate shall also be issued with a Diploma Supplement.

(4) The Diploma Supplement is an addition to the certificate in German and English with standard information about German university degree qualifications; it explains the German education system and the place of the present degree qualification in it. The Diploma Supplement provides information about the completed degree program and the academic and professional qualifications achieved with it. The Diploma Supplement includes the central content of the program on which it is based, the program of study, the skills achieved on graduation, and the awarding university.

Section 25
Master's Certificate

(1) Along with the certificate for completion of the degree, the candidate shall be provided with a Master's Certificate with the date of the certificate. This certifies the award of the master's degree in accordance with Section 2.

(2) The Master's Certificate shall be signed by the Dean of the Faculty of Science and the Chair of the Examinations Board and provided with the seal of Paderborn University.

(3) An English translation shall be attached to the Master's Certificate.

III. Final provisions

Section 26
Invalidity of the master's examination

(1) If a candidate has engaged in unfair practice in an examination and if this fact only becomes apparent after the certificate has been issued, the Examinations Board may subsequently adjust the grades accordingly for those examinations in which the candidate engaged in unfair practice and declare the examination failed in whole or in part.

(2) If the requirements for admission to an examination were not met, without the candidate intending to deceive, and if this fact becomes apparent only after the certificate has been issued, this defect shall be remedied by passing the exam. If the candidate has intentionally brought about admission by deceit, the Examinations Board shall decide on the legal consequences, taking account of the Administrative Procedures Act for the region of Nordrhein-Westfalen.

(3) The candidate shall be given the opportunity to speak before any decision is made.

(4) The incorrect examination certificate shall be retracted and, if appropriate, a new one shall be issued. A decision in accordance with paragraph 1 and paragraph 2 clause 2 is excluded after a period of five years from the date of issue of the examination certificate.

(5) If the examination as a whole has been declared to have been failed, the master's degree shall be withdrawn and the Master's Certificate retracted. Withdrawal of the master's degree is permitted only within five years of the date on which the degree was awarded.

Section 27
Access to the examination files

(1) Following release of the grades, the candidate may be given the opportunity to have access to her or his written assessments and the evaluation of the examiners relating to them. The Chair of the Examinations Board shall determine the location and time at which access is provided; she or he may assign these tasks to the examiners. The location and time at which access is provided shall be made known during the examination, at the latest on release of the grade.

(2) If paragraph 1 does not apply, on application within a month of release of the results of the respective examinations the candidate shall be given the opportunity to have access to her or his written assessments and the evaluations of the examiners relating to them and to the examination records. Within one year of issue of the certificate, the candidate shall be given access on request to the master's thesis, the related evaluations of the examiners, and the examination records within an appropriate period. The Chair of the Examinations Board shall determine the location and time at which access is provided; she or he may assign these tasks to the examiners.

Section 28
Withdrawal of the master's degree

The master's degree shall be withdrawn if it subsequently transpires that it has been obtained by unfair practice or if significant requirements for the award have mistakenly been considered to have been met. The Faculty Board of the Faculty of Science of Paderborn University shall decide on the withdrawal by a two-thirds majority of its members. Withdrawal of the master's degree is permitted only within five years of the date on which the degree was awarded.

Section 29
Effectiveness, publication, and transitional provisions

(1) These Examination Regulations shall come into force on October 1, 2017.

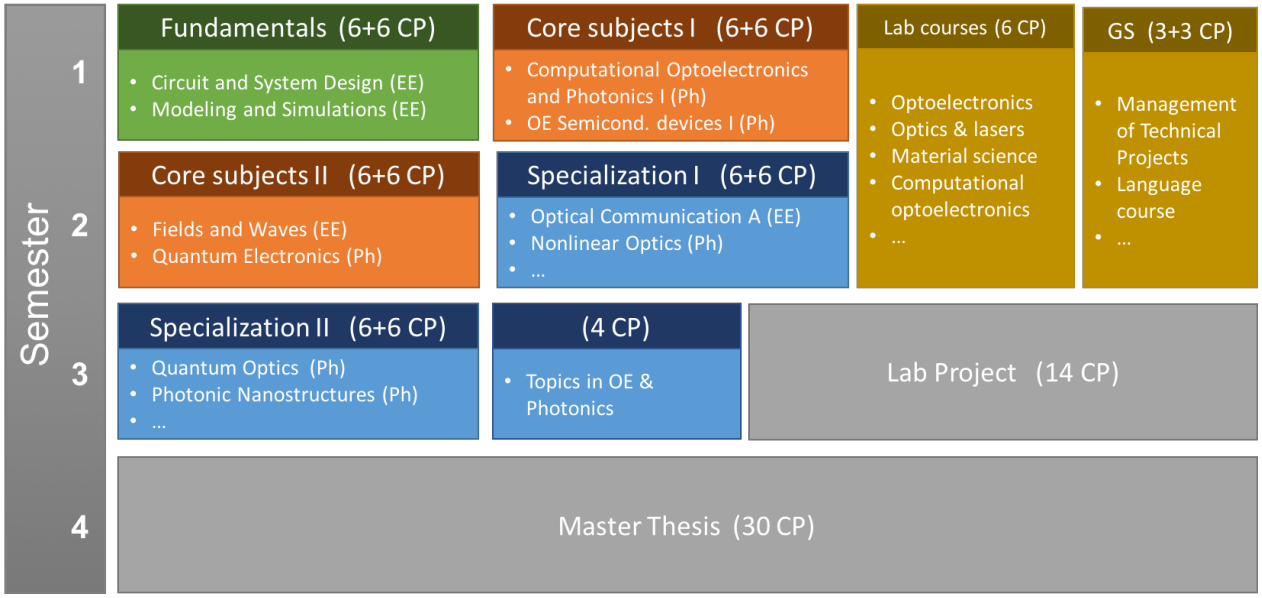
(2) These Examination Regulations shall be published in the Official Bulletin of Paderborn University (AM.Uni.Pb.).

Drafted on the basis of the resolution of the Faculty Board of the Faculty of Science of May 17, 2017 and checked for legal compliance by the Executive Board of Paderborn University on May 24, 2017.

Paderborn, June 16, 2017

On behalf of theThe President
The Vice-President for Operations
of Paderborn University
Simone Probst

Appendix: curriculum and module description



120 CP in total.

Curriculum

Semester	Module oder Module group	Module	Workload (h)	Total workload (h)
1. Semester	Fundamentals	Circuit and System Design	180	
	Fundamentals	Modelling and Simulations	180	
	Core Subjects I	Optoelectronic Semiconductor Devices	180	
	Core Subjects I	Computational Optoelectronics and Photonics I	180	
	Lab courses	2 elective lab practicals	90	
	General Studies	1 elective module	90	900
2. Semester	Core Subjetcs II	Quantum Electronics	180	
	Core Subjects II	Fields and Waves	180	
	Specialization I	1 elective module	180	
	Specialization I	1 elective module	180	
	Lab courses	2 elective lab practical	90	
	General Studies	1 elective module	90	900
3. Semester	Specialization II	1 elective module	180	
	Specialization II	1 elective module	180	
	Topics in Optoelectronics and Photonics	Topics in Optoelectronics and Photonics	120	
	Lab Project	Lab Project	420	900
4. Semester	Master's Thesis	Master's Thesis	750	
		Oral Defense	150	900

This curriculum is intended as a recommendation and guidance and can be individually rearranged. The requirements for admission to certain modules as detailed in the module descriptions must be observed in this case.

Module list

Module group Fundamentals of Optoelectronics	Contact hours per week and semester	Credit points
Circuit and System Design (EE)	Lect. 2; Exerc. 2	6
Modelling and Simulation (EE)	Lect. 2; Exerc. 2	6

Module group Core Subjects I	Contact hours per week and semester	Credit points
Optoelectronic Semiconductor Devices	Lect. 2; Exerc. 2	6
Computational Optoelectronics and Photonics I	Lect. 2; Exerc. 2	6

Module group Core Subjects II	Contact hours per week and semester	Credit points
Quantum Electronics	Lect. 2; Exerc. 2	6
Fields and Waves (EE)	Lect. 2; Exerc. 2	6

Module group Specialization in Optoelectronics and Photonics	Contact hours per week and semester	Credit points
Typically held in summer terms:		
Nonlinear Optics	Lect. 2; Exerc. 2	6
Optical Communication A (EE)	Lect. 2; Exerc. 2	6
Optical Communication B (EE)	Lect. 2; Exerc. 2	6
Computational Optoelectronics & Photonics II	Lect. 2; Exerc. 2	6
Quantum Communication and Information	Lect. 2; Exerc. 2	6
Optics of solid-state systems and nanostructures	Lect. 2; Exerc. 2	6
Theory of Quantum Information	Lect. 2; Exerc. 2	6
Theoretical Quantum Optics	Lect. 2; Exerc. 2	6
Sensor Technology	Lect. 2; Exerc. 2	6
Typically held in winter terms:		
Integrated Optics and Photonics	Lect. 2; Exerc. 2	6
Quantum Optics	Lect. 2; Exerc. 2	6
Physics and Technology of Nanomaterials	Lect. 2; Exerc. 2	6
Electromagnetic Field Simulations (EE)	Lect. 2; Exerc. 2	6
Fast integrated circuits for wireline communications (EE)	Lect. 2; Exerc. 2	6

Photonic Nanostructures	Lect. 2; Exerc. 2	6

Further modules	**Contact hours per week and semester**	**Credit points**
Lab Courses	Lab 4	6
Topics in Optoelectronics & Photonics	Sem 2	4
Lab Project		14
Master Thesis (Master's thesis incl. oral defense)		30
General Studies, to be chosen from the catalogue of Paderborn University		6

Module Descriptions

Circuit and System Design

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Fundamentals of optoelectronics	180	6	1	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Circuit and System Design	Lect	30	60	Compuls.	up to 240
b)	Circuit and System Design	Exerc	30	60	Compuls.	up to 30

2 Options within the module

None

3 Admission requirements

Good knowledge in differential equations, Laplace transform, Fourier transform, electrical network analysis (Kirchhoff's laws etc.), Electron devices (pn-diode, MOS transistor, bipolar transistor), basic digital design (boolean algbra, logic gates etc.) *Information: Unless otherwise specified, these are recommendations.*

4 Contents

Short Description

The lecture gives an introduction to analysis and design of analog and digital circuits and systems. It builds on basic knowledge of electron devices (bachelor-level) and the compulsory lectures "Advanced System Theory" and "Modeling and Simulation".

Contents

- Analysis methods for analog systems
- Analysis methods for digital systems
- Elementary analog and digital circuits
- Modeling and numerical simulation of analog and digital circuits and systems
- Typical components and subsystems
- Application examples

5 Learning outcomes and competences

Domain competence:

The students will be able to

- describe appropriate methods for analysis and design of analog systems
- describe appropriate methods for analysis and design of digital systems
- assess the limitations of the different methods
- understand and calculate the behaviour of simple analog and digital circuits
- use a numeric simulation tool for electronic systems and circuit simulation
- describe typical components and subsystems

Key qualifications:

The lecture conveys an understanding of the interaction of different modeling techniques, mathematical analysis approaches, and numerical simulation, as well as how to apply these effectively to the design of technical systems. The methods for analog electronic design are transferrable to the design of continuous-time, continuous-amplitude systems. The methods for digital design are transferrable to the design of discrete-time, discrete-amplitude systems.

6 Assessments

Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

7 Certified participation

None

8 Prerequisites for participation in examinations

None

9 Prerequisites for assigning credits

The credit points are awarded after the module examination (MAP) was passed.

10 Weight for overall grade

The module is weighted according to the number of credits (factor 1).

11 Reuse in degree courses

12 Module coordinator

Prof. Dr.-Ing. Christoph Scheytt

13 Other notes

	Implementation • Lecture with PowerPoint presentation and handwritten mathematical derivations using tablet and beamer • One part of the exercises as handwritten calculation exercises using tablet and beamer • Other part of exercises as practical design tasks using using LTspice simulation **Teaching Material, Literature** Handouts and literature references will be given in the lecture.

Modeling and Simulation

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Fundamentals of optoelectronics	180	*6*	1	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Modeling and Simulation	Lect	30	60	Compuls.	up to 240
b)	Modeling and Simulation	Exerc	30	60	Compuls.	up to 30

2 Options within the module

None

3 Admission requirements

- Prior knowledge of programming in Matlab will be required
- Knowledge of mathematics and physics at the level of the university entrance qualification

Information: Unless otherwise specified, these are recommendations.

4 Contents

Short Description

In this lecture, techniques of constructing models and simulations of technical systems are introduced and implemented.

Contents

- Introduction to the modeling process
- Number representation in digital computers
- Numerical schemes for ordinary and partial differential equations
- Discrete simulations

5 Learning outcomes and competences

Domain competence:

After attending the course, the students will be able to

- categorize and analyze modelling schemes and numerical methods
- identify and apply numerical methods for technical-physical systems
- illustrate and physically evaluate the obtained results
- extend, develop and validate numerical algorithms

6 Assessments

Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

7	**Certified participation**
	None
8	**Prerequisites for participation in examinations**
	None
9	**Prerequisites for assigning credits**
	The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade**
	The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses**
12	**Module coordinator**
	Prof. Dr. rer. nat. Jens Förstner
13	**Other notes**
	Module Homepage **Implementation** The theoretical concepts are taught in lecture form. The exercises consist of simple questions to be discussed as well as classical mathematical problems which are to be solved by the students in self- contained manner. Further, the students will use self-written as well as commercial software for selected topics.

Optoelectronic Semiconductor Devices

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	1st	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Optoelectronic Semiconductor Devices	Lect	30	60	Compuls.	up to 240
b)	Optoelectronic Semiconductor Devices	Exerc	30	60	Compuls.	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

The first part of the lecture gives an overview of the physics of light-emitting diodes and the static properties of semiconductor lasers starting from basic solid-state physics up to the design and operation of the most important semiconductor LEDs and laser diodes. The second part deals with the dynamic properties of semiconductor lasers, their spectral properties and the principles of various semiconductor photodetectors.

- Relevance of optoelectronic semiconductor devices
- Light-emitting diodes – LED
- Laser diodes – static properties
- Laser diodes – dynamic properties
- Optoelectronic detectors

5 Learning outcomes and competences:

The students are expected to understand the fundamental concepts of optoelectronic semiconductor devices and to be able to apply these to relevant problems on their own.

The students

- know the fundamental principles of light-emitting semiconductor devices, such as LEDs or laser diodes,
- have a physical understanding of the static, dynamic and spectral properties of LEDs and semiconductor lasers,
- can apply their fundamental knowledge of the influence of quantum structures on the properties of modern semiconductor devices,
- are able to apply their knowledge to the design and operation of optoelectronic semiconductor devices,
- have a basic knowledge of the functional principles and the areas of application of various semiconductor photodetectors.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

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<tr><th>To</th><th>Form</th><th>Duration or length</th><th>Certified participation</th></tr>
<tr><td></td><td></td><td></td><td>None</td></tr>
</table></td></tr>
<tr><td>8</td><td>Requirements for participating in examinations:</td></tr>
<tr><td></td><td>None</td></tr>
<tr><td>9</td><td>Requirements for awarding credit points:</td></tr>
<tr><td></td><td>Credit points are awarded if the final module examination has been passed.</td></tr>
<tr><td>10</td><td>Weight for overall grade:</td></tr>
<tr><td></td><td>The module is weighted according to credit points (factor: 1).</td></tr>
<tr><td>11</td><td>Use of the module in other programs:</td></tr>
<tr><td></td><td>The module is also used in the master program Physics.</td></tr>
<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Prof. Dr. Dirk Reuter, Prof. Dr. Donat As</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Computational Optoelectronics and Photonics I

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	1st	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Computational Optoelectronics and Photonics I	Lect	30	60	Compuls.	up to 240
b)	Computational Optoelectronics and Photonics I	Exerc	30	60	Compuls.	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

- Application-oriented introduction to the practical numerical implementation of mathematical problems and the visualization of computed data
- Propagation of light in nanostructured solids
- Quantum-mechanical oscillator inside an optical resonator
- Excitons in low-dimensional semiconductor systems coupled to propagating light fields
- Localized electronic states and their properties in nanostructures
- Basic models of quantum optics and quantum information

5 Learning outcomes and competences:

The students

- obtain a basic understanding of nanostructured solids and their applications in photonic structures based on specific examples,
- are able to numerically implement relevant equations used for the mathematical description of physical systems,
- are able, with guidance, to write their own source codes and to use existing program packages in order to numerically analyze the problems formulated in the lecture,
- are able, with guidance, to numerically treat and analyze high-dimensional systems of nonlinear equations of motion,
- can visualize complex physical problems and display the results appropriately.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

<table>
<tr><td>7</td><td>Certified participation:
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<tr><td></td><td></td><td></td><td>None</td></tr>
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<tr><td></td><td>None</td></tr>
<tr><td>9</td><td>Requirements for awarding credit points:</td></tr>
<tr><td></td><td>Credit points are awarded if the final module examination has been passed.</td></tr>
<tr><td>10</td><td>Weight for overall grade:</td></tr>
<tr><td></td><td>The module is weighted according to credit points (factor: 1).</td></tr>
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<tr><td></td><td>The module is also used in the master program Physics.</td></tr>
<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Prof. Dr. Stefan Schumacher, Dr. Matthias Reichelt</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Quantum Electronics

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	2nd	Summer semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Quantum Electronics	Lect	30	60	Compuls.	up to 240
b)	Quantum Electronics	Exerc	30	60	Compuls.	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

Basic concepts of quantum electronics, their optical, electrical and optoelectronic foundations as well as their practical applications. Understanding and mathematical formulation of the physical issues and models.

- Experimental characterization of quantum systems
- Atoms and quantum structures as two-level systems
- Coherent light-matter interaction
- Quantum amplifiers
- Solid-state quantum bits
- Quantum bits in strong optical fields and resonators
- Functional structures and practical applications

5 Learning outcomes and competences:

The students

- possess a profound technical knowledge in the area of quantum electronics,
- possess a profound knowledge about two-level systems,
- possess a profound knowledge about the light-matter interaction in strong fields,
- are able to mathematically describe the physical principles of quantum electronics,
- are able to derive fundamental physical principles of quantum electronics,
- can clearly communicate the physical and technical foundations as well as practical applications of quantum electronics.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

<table>
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<tr><td>11</td><td>Use of the module in other programs:</td></tr>
<tr><td></td><td>This module is also used in the master program Physics.</td></tr>
<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Prof. Dr. Artur Zrenner, Prof. Dr. Christine Silberhorn</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Fields and Waves

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Core subjects II	180	6	2	Summer semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Fields and Waves	Lect	30	60	Compuls.	up to 240
b)	Fields and Waves	Exerc	30	60	Compuls.	up to 30

2 Options within the module

None

3 Admission requirements

None

4 Contents

Short Description

Introduction in the Maxwellian theory of electromagnetic fields and waves, from fundamentals up to the analysis of several wave guiding structures.

Contents

Recapitulation of Basics (Maxwell's equations, constitutive relations, continuity conditions, energy), the wave equation and its solutions , Snell's law and Fresnel formulas, dispersion, waveguides, radiation of waves

5 Learning outcomes and competences

Domain competence:

After attending the course, the students will be able

- to mathematically model time harmonic electromagnetic field problems
- to identify and apply appropriate analytical methods
- to physically interpret and visualize the obtained results
- to extend, develop and validate theoretical models for electromagnetic field problems

Key qualifications:

The students

- learn to transfer the acquired skills also to other disciplines
- extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises
- learn strategies to acquire knowledge from literature and internet
- acquire a specialized foreign language competence

6 Assessments

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. or 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

Certified participation:

To	Form	Duration or length	Certified participation
			None

7	**Certified participation**
	None
8	**Prerequisites for participation in examinations**
	None
9	**Prerequisites for assigning credits**
	The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade**
	The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses**
12	**Module coordinator**
	Prof. Dr. Jens Förstner
13	**Other notes**

Implementation

The theoretical concepts are taught in lecture form. The exercises consist of simple questions to be discussed as well as classical field problems with mathematical solutions which are to be solved by the students in self-contained manner.

Teaching Material, Literature

Slides and lecture notes, additional recommendations for textbooks will be given in the course.

Nonlinear Optics

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Experimental Physics	180	6	2nd	Summer semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Nonlinear Optics	Lect	30	60	Elective	up to 240
b)	Nonlinear Optics	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

- Nonlinear optical susceptibility (description of nonlinear optical processes, formal definition and properties of the nonlinear susceptibility)
- Wave-optical description of nonlinear interactions (wave equation for nonlinear optical media, phase matching, Manley-Rowe relation, SHG and SFG, nonlinear optics at interfaces)
- Intensity-dependent refractive index (semiconductor nonlinearities, pulse propagation and solitons, optical phase conjugation, optical bistability)
- Electro-optical and photorefractive effects (electro-optical effect, electro-optical modulators, photorefractive effect)

5 Learning outcomes and competences:

The students are expected to be capable of applying the fundamental concepts of nonlinear optics correctly and effectively to typical problems in physics and of solving these on their own.

The students

- can identify and analyze questions in the field of nonlinear optics and recognize the differences with respect to linear optics,
- can apply approximations to solve nonlinear wave equations,
- can independently identify problems in nonlinear optics and develop appropriate strategies to solve standard problems that include nonlinear effects,
- are able to make simple abstractions of more complex problems when dealing with nonlinear optical effects and to transfer these to approximations for solving the problems,
- have the ability to independently assess complex physical relationships in nonlinear optics and to evaluate numerical or analytical approaches to their approximations using the acquired knowledge,
- can deal with current English-language literature on topics of nonlinear optics on their own.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

	Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.
7	**Certified participation:**

To	Form	Duration or length	Certified participation
			None

8	**Requirements for participating in examinations:**
	None
9	**Requirements for awarding credit points:**
	Credit points are awarded if the final module examination has been passed.
10	**Weight for overall grade:**
	The module is weighted according to credit points (factor: 1).
11	**Use of the module in other programs:**
	The module is also used in the master program Physics.
12	**Module coordinator:**
	Prof. Dr. Thomas Zentgraf, Prof. Dr. Christine Silberhorn
13	**Further notes:**
	None

Optical Communication A

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	1-3	Summer semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Optical Communication A	Lect	30	60	Elective	up to 240
b)	Optical ,Communication A	Exerc	30	60	Elective	up to 30

2 Options within the module

None

3 Admission requirements

None

4 Contents

Short Description

The lecture Optical Communication A gives basic knowledge in Optical Communication and the components used in this field.

Contents

Fundamentals (4 SWS, 6 ECTS credit points): Maxwell's equations, wave propagation, polarization, dielectric slab and cylindrical waveguides, dispersion, laser, photodiodes, optical amplifiers, modulation, signal formats, optical receivers, noise, regenerators, wavelength division multiplex. Here the most important knowledge is taught.

5 Learning outcomes and competences

Professional Competence

After attending the course, the students will be able, in the taught subjects, to

- describe, model and apply the function of components, systems and effects of optical communications and
- apply knowledge of optoelectronics

(Soft) Skills

The students

- are able to apply the knowledge and skills to a wide range of disciplines,
- are able to make use of a methodical procedure when undertaking systematic analysis and
- are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves

6 Assessments

Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

7	**Certified participation**
	None
8	**Prerequisites for participation in examinations**
	None
9	**Prerequisites for assigning credits**
	The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade**
	The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses**
	EMA, WGMAET, CEMA, ESEMA, MA LABKET
12	**Module coordinator**
	Prof. Dr.-Ing. Reinhold Noé
13	**Other notes**

Teaching Material, Literature

Scripts, exercise sheets and advanced literature (excerpt):

- R. Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7
- Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag 2002
- D. As, Univ. Paderborn, Vorlesung Optoelektronik
- W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik
- G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991
- K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992
- H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter)
- Yariv, Optical Electronics, Holt, 1984
- R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

Optical Communication B

Module group:	Workload (h):	CP:	Semester of study:	Cycle	Duration (in sem.):
Specialization	180	6	1-3	Summer semester	1

Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Optical Communication B	Lect	30	60	Elective	up to 240
b)	Optical Communication B	Exerc	30	60	Elective	up to 30

2 Options within the module

None

3 Admission requirements

None

4 Contents

Short Description

The lecture Optical Communication B gives some knowledge about mode coupling in Optical Commu- nication and explains the function of many optical components.

Contents

Mode Coupling (4 SWS, 6 ECTS credit points): Polarization mode dispersion, moden orthogonality, constant and periodic, co- and counterdirectional mode coupling, profiles of differential group delay, electrooptic effect. The function of many passive and active optical elements is thereby explained, among others amplitude and phase modulators, broadband and wavelength-selective couplers, Bragg gratings, polarization-maintaining fibers, polarization transformers, equalizers for polarization mode dispersion and chromatic dispersion.

5 Learning outcomes and competences

Professional Competence

After attending the course, the students will be able, in the taught subjects, to

- describe, model and apply the function of components, systems and effects of optical communications and
- apply knowledge of optoelectronics

(Soft) Skills

The students

- are able to apply the knowledge and skills to a wide range of disciplines,
- are able to make use of a methodical procedure when undertaking systematic analysis and
- are, due to the abstract and precise treatment of the contents, in a position to continue and develop their learning themselves

6 Assessments

Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written or oral examination or presentation	120–180 min. or 30–45 min. or 30 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

Certified participation:

To	Form	Duration or length	Certified participation
			None

8	**Prerequisites for participation in examinations**
	None
9	**Prerequisites for assigning credits**
	The credit points are awarded after the module examination (MAP) was passed.
10	**Weighing for overall grade**
	The module is weighted according to the number of credits (factor 1).
11	**Reuse in degree courses**
	EMA, WGMAET, CEMA, ESEMA, MA LABKET
12	**Module coordinator**
	Prof. Dr.-Ing. Reinhold Noé
13	**Other notes**

Teaching Material, Literature

Scripts, exercise sheets and advanced literature (excerpt):

- Noe, Essentials of Modern Optical Fiber Communication, Springer, 2. Auflage / 2nd Edition, 2016, ISBN 978-3-662-49621-3, ISBN ISBN 978-3-662-49623-7
- Petermann/Voges, Optische Kommunikationstechnik, Springer-Verlag 2002
- D. As, Univ. Paderborn, Vorlesung Optoelektronik
- W. Sohler, Univ. Paderborn, Vorlesung Integrierte Optik
- G. Grau, W. Freude, Optische Nachrichtentechnik, Springer-Verlag, Heidelberg, 1991
- K.J. Ebeling, Integrierte Optoelektronik, Springer-Verlag, Heidelberg, 1992
- H.-G. Unger, Optische Nachrichtentechnik, Teile I und II, Hüthig-Verlag Heidelberg, 1984 und 1985, (Schwerpunkt optische Wellenleiter)
- Yariv, Optical Electronics, Holt, 1984
- R. Th. Kersten, Einführung in die Optische Nachrichtentechnik, Springer-Verlag

Computational Optoelectronics and Photonics II

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (sem.):
Specialization	180	6	2nd	Summer semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Computational Optoelectronics and Photonics II	Lect	30	60	Elective	up to 240
b)	Computational Optoelectronics and Photonics II	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

- Application of many-particle methods to nanostructured photonic systems
- Numerical analysis of electronic states in low-dimensional structures
- Numerical analysis of optical nonlinearities in low-dimensional structures
- Propagation of light coupled to the nonlinear optical excitations in a material
- Applications of nonlinear optical propagation effects, such as bistability and solitons

5 Learning outcomes and competences:

The students

- deepen, building on the module Optoelectronics and Photonics I, their understanding of nanostructured solids and their application in photonic structures, based on specific examples,
- are able to apply methods of many-particle theory to nanostructured solids and to numerically solve the resulting equations,
- are able to compute the nonlinear optical response of nanostructured solids,
- can independently implement mathematical formulations of physical models numerically,
- can independently develop computer codes in order to numerically analyze problems covered in the lectures.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

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<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Prof. Dr. Stefan Schumacher, Dr. Matthias Reichelt</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Quantum Communication and Information

Quantenkommunikation und Quanteninformationsverarbeitung

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	2nd	Summer semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Quantum Communication and Information	Lect	30	60	Elective	up to 240
b)	Quantum Communication and Information	Exer	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

The module aims to impart the basic concepts and protocols of quantum communication and quantum information processing.

- Introduction to the underlying principles of quantum information (mathematical formulation of the concept of information, qubits and quantum gates)
- Quantum measurements
- Entangled states
- Quantum teleportation and quantum dense coding
- Quantum cryptography (protocols, experimental implementations, security proofs and eavesdropper attacks)
- Entanglement distillation and quantum repeaters

5 Learning outcomes and competences:

The students are expected to understand the underlying concepts of quantum communication and to know the main protocols and their practical implementations.

The students

- are able to work on interdisciplinary topics and, in particular, to acquire the basics of different disciplines,
- are familiar with the abstract concepts of information theory and quantum physics, and they can relate these with relevant experiments from physics,
- understand the fundamental idea of novel quantum technologies, the exploitation of genuine quantum-physical characteristics for practical applications,
- understand the notion of entangled states and its relevance for the modern interpretation of quantum physics,
- know the basic protocols of quantum communication and quantum information processing,
- are able to familiarize themselves with contemporary research topics, which may not yet be presented in textbooks, and thus they get prepared for future independent research work,
- can realistically evaluate the prospects and limitations of future technologies.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

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<tr><td></td><td>The module is also used in the master program Physics.</td></tr>
<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Prof. Dr. Christine Silberhorn</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Optics of Solid-State Systems and Nanostructures

Optik in Festkörpern und Nanostrukturen

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	2nd	Summer semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Optics of Solid-State Systems and Nanostructure	Lect	30	60	Elective	up to 240
b)	Optics of Solid-State Systems and Nanostructure	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

- Semiclassical description of light-matter interaction in solids and nanostructures
- Linear and nonlinear optical properties of two- and multi-level systems
- Optical Bloch equations
- Rabi oscillations, quantum beats
- Theoretical description of pump-probe and four-wave-mixing experiments
- Microscopic many-body theory for optical excitations in semiconductors and nanostructures
- Semiconductor Bloch equations
- Excitons and further many-body effects
- Relaxation and dephasing
- Self-consistent description of light propagation in solid-state systems and nanostructures

5 Learning outcomes and competences:

The students

- know the derivation and the basic properties of the optical Bloch equations,
- are able to solve the optical Bloch equations using different approximation strategies and to use their results for the description of linear and nonlinear optical properties,
- are familiar with concepts to describe many-body effects in semiconductor optics and can apply these to the derivation of the semiconductor Bloch equations,
- are able to calculate excitonic effects in linear optical spectra within the framework of the semiconductor Bloch equations and to describe nonlinear optical properties within additional approximations,
- know the basic physical processes that lead to dephasing of the optical polarization and to the energy relaxation of optically excited carrier populations,
- know the basic concepts of the self-consistent description of the light propagation in solids and are able to approximately calculate fundamental effects for simple geometries,
- are aware of the capabilities and limitations of the semiclassical description of the light-matter interaction and can use this knowledge to assess results from the literature.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

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9	**Requirements for awarding credit points:**
	Credit points are awarded if the final module examination has been passed.
10	**Weight for overall grade:**
	The module is weighted according to credit points (factor: 1).
11	**Use of the module in other programs:**
	The module is also used in the master program Physics.
12	**Module coordinator:**
	Prof. Dr. Torsten Meier, Prof. Dr. Stefan Schumacher
13	**Further notes:**
	None

Theory of Quantum Information

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	2nd	Summer semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Theory of Quantum Information	Lect	30	60	Elective	up to 240
b)	Theory of Quantum Information	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

- Quantum mechanics in modern formulation (states, effects, operations and representation theorems)
- Separability and nonseparability of statistical operators
- Einstein-Podolsky-Rosen paradox
- Quantum cryptography
- Quantum computing
- Quantum teleportation

5 Learning outcomes and competences:

The students are expected to learn fundamental concepts of the theory of quantum information and to be capable of comprehending current research articles and performing basic calculations on their own.

The students

- know the modern formulation of quantum mechanics,
- are familiar with the concept of separability/nonseparability and can apply this to statistical operators,
- know the ideas and interpretations that underlie the Einstein-Podolsky-Rosen paradox as well as the quantum-mechanical description of entangled states,
- know the fundamental processes that form the basis of quantum cryptography, quantum computing and quantum teleportation, and they can describe these phenomena with the help of model systems.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

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<tr><td></td><td>The module is also used in the master program Physics.</td></tr>
<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Prof. Dr. Torsten Meier, Dr. Matthias Reichelt</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Theoretical Quantum Optics

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	2nd	Summer semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Theoretical Quantum Optics	Lect	30	60	Elective	up to 240
b)	Theoretical Quantum Optics	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

- Canonical quantization of fields
- Fock states, coherent states, squeezed light
- Statistics of photons
- Phase-space functions (*P*, *W*, *Q* function)
- Bunching and antibunching
- Quantum theory of light-matter interaction
- Jaynes-Cummings model, dressed states

5 Learning outcomes and competences:

The students are expected to learn fundamental concepts of theoretical quantum optics and to be capable of comprehending current research articles and performing basic calculations on their own.

The students

- know the concept of photons and how to use photon operators,
- know the theoretical description of light states that can be prepared in modern experiments,
- are familiar with the statistical properties of light and can interpret measurements on this basis,
- know the phase-space functions of common light states,
- know the different behavior of classical and quantized light with respect to the light-matter interaction,
- know the derivation and analysis of the Jaynes-Cummings model and can transfer this to simple extended model systems.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

7	**Certified participation:** **To** | **Form** | **Duration or length** | **Certified participation** | | | | none
8	**Requirements for participating in examinations:**
	None
9	**Requirements for awarding credit points:**
	Credit points are awarded if the final module examination has been passed.
10	**Weight for overall grade:**
	The module is weighted according to credit points (factor: 1).
11	**Use of the module in other programs:**
	The module is also used in the master program Physics.
12	**Module coordinator:**
	Dr. Matthias Reichelt, Prof. Dr. Torsten Meier
13	**Further notes:**
	None

Sensor Technology

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	2nd	Summer semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Sensor Technology	Lect	30	60	Elective	up to 240
b)	Sensor Technology	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

- *The lecture Sensor Technology describes the physical behaviour of typical sensors and their applications in industry. Ranges and limitations of the sensors are presented. The lecture includes thermal sensors, force and magnetic sensors, gas and humidity sensitive devices*

Temperature Sensors:

- *Metal Resistors*
- *NTC*
- *PTC*
- *Junction Sensor*
- *Spreading Resistance Temperature Sensor*
- *Thermoelectric Sensors*

Optical Sensors:

- *Resistances and Diodes*
- *Photo Transistors*
- *CCD*
- *Thermal Column*

Magnet Field Sensors:

- *Hall Sensor*
- *Gauss Sensor Plate*
- *Ferromagnetic Resistive Sensors*
- *Split Drain Transistor*
- *Magneto Diode*
- *Flux-Gate-Sensor*

Acceleration Based Sensors:

<table>
<tr><td></td><td>

- *Force*
- *Acceleration*
- *Rotation Rate Sensors*

Gas Sensors:

- *Metal-Oxide Sensors*
- *Catalytic Sensors*
- *SAW Sensors*

</td></tr>
<tr><td>5</td><td>

Learning outcomes and competences:

***Domain competence*:**

The students are able to describe the operation principle of different kinds of sensor devices and can choose a suitable sensor for a given application. They can explain the setup or manufacturing processes for the sensor devices. They can write down the sensitivity of different kind of sensors.

***Key qualifications*:**

The students learn:

- to transfer the knowledge of sensor devices to other applications

- to work in groups to solve problems

- thinking in systems, not on device level

</td></tr>
<tr><td>6</td><td>

Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

</td></tr>
<tr><td>7</td><td>

Certified participation:

To	Form	Duration or length	Certified participation
			none

</td></tr>
<tr><td>8</td><td>Requirements for participating in examinations:</td></tr>
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<tr><td>10</td><td>Weight for overall grade:</td></tr>
<tr><td></td><td>The module is weighted according to credit points (factor: 1).</td></tr>
</table>

11	**Use of the module in other programs:**
12	**Module coordinator:**
	Prof. Dr. Ing. Ulrich Hilleringmann
13	**Further notes:**
	Teaching materials: Elvensproek: Mechanical Microsensors Handbook of Sensor Devices

Integrated Optics and Photonics

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	3rd	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Integrated Optics and Photonics	Lect	30	60	Elective	up to 240
b)	Integrated Optics and Photonics	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

- Propagation of electromagnetic waves in optical waveguides (wave equation, boundary conditions and modal dispersion relations of planar waveguides)
- Selected materials and fabrication methods (ion exchange in glasses and crystals, indiffused waveguides in $LiNbO_3$, epitaxially grown waveguides in semiconductor materials)
- Coupled-mode theory (description via eigenmodes of the unperturbed system, description via local normal modes of the actual system)
- Electro-optic devices (electro-optic effect in dielectric crystals, modulators and switches)
- Nonlinear optical devices

5 Learning outcomes and competences:

The students are expected to understand the underlying concepts of integrated optics and photonics as well as their applications.

The students

- have the ability to recognize and analyze questions and problems in integrated optics and to distinguish them from conventional classical optics,
- are able to quantitatively describe wave propagation in guided structures and to apply this (with approximations) to different waveguide geometries on their own,
- are capable of describing the functional principle of integrated optical devices, based on underlying physical principles, and of modelling simple devices on their own either analytically or numerically using the coupled-mode theory,
- are able to autonomously analyze complex integrated optical structures, to identify the different functional components and to describe their roles within the structure,
- can independently study current scientific articles (written in English) on integrated optical devices and photonic structures.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade

	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

7 **Certified participation:**

To	Form	Duration or length	Certified participation
			None

8 **Requirements for participating in examinations:**

None

9 **Requirements for awarding credit points:**

Credit points are awarded if the final module examination has been passed.

10 **Weight for overall grade:**

The module is weighted according to credit points (factor: 1).

11 **Use of the module in other programs:**

The module is also used in the master program Physics.

12 **Module coordinator:**

Prof. Dr. Christine Silberhorn, Dr. Harald Herrmann

13 **Further notes:**

None

Quantum Optics

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	3rd	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Quantum Optics	Lect	30	60	Elective	up to 240
b)	Quantum Optics	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

In this module, the underlying concepts required to study quantum optics using light are presented. The following topics are discussed in detail:

- Photon statistics and detection of quantum light
- Underlying principles of field quantization
- Coherent states and phase-space representation of light
- Beam splitters and interferometers in quantum optics
- Nonclassical light, squeezed states
- Correlation functions and quantum coherence

5 Learning outcomes and competences:

The students are expected to understand the fundamental concepts of quantum optics, including knowledge of specific phenomena that distinguish quantum-optical observations from their classical counterparts.

The students

- are comfortable with abstract theoretical concepts from quantum optics and can relate these to concrete experimental scenarios,
- are able to use calculation methods from theoretical quantum mechanics in order to solve practical problems in experimental quantum optics,
- can distinguish specific quantum-optical observations from purely classical optical experiments,
- understand the principle of field quantization and the implications for the definition of a photon and the formally correct characterization of wave-particle duality,
- understand the modelling of “classical” laser light and the significance of photon statistics,
- are proficient in calculating quantum interference in a range of setups,
- can judge the applicability of nonclassical states of light in practical scenarios.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

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<tr><td></td><td>The module is also used in the master program Physics.</td></tr>
<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Prof. Dr. Christine Silberhorn, Jun.-Prof. Dr. Tim Bartley</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Physics and Technology of Nanomaterials

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	3rd	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Physics and Technology of Nano-materials	Lect	30	60	Elective	up to 240
b)	Physics and Technology of Nano-materials	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

- Thermodynamic and crystallographic foundations of nanomaterials
- Preparation of thin films from the liquid phase and vacuum
- Patterning and modification of thin films using thermal, wet-chemical, ion-beam-assisted and plasma-based processes
- Lateral structuring of thin films and surfaces using conventional and advanced lithography processes
- Preparation, processing and application of one-, two- and three-dimensional nanoobjects (nanowires and nanotubes, graphene and related materials, nanoclusters, core-shell structures)

5 Learning outcomes and competences:

The students acquire the skills to develop technological concepts for the preparation of nanostructured materials and to evaluate the prospects for their technical realization.

The students

- understand the particular properties that materials acquire by means of nanostructuring,
- know different basic concepts and processes for the preparation of structures with nanoscale size in one, two or three dimensions,
- understand the physical background of these processes at the atomistic or molecular level,
- can employ qualitative and quantitative models that describe such processes,
- are able to transfer the methods to new problems and materials across disciplinary boundaries and to combine them in different ways,
- are capable of autonomously learning about additional technologies by studying technical literature and online sources and to present these in a well-considered manner.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start

<table>
<tr><td></td><td>of teaching by the teacher concerned.</td></tr>
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<tr><td>11</td><td>Use of the module in other programs:</td></tr>
<tr><td></td><td>The module is also used in the master programs Physics as well as Materials Science.</td></tr>
<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Prof. Dr. Jörg Lindner, Prof. Dr. Dirk Reuter</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Electromagnetic field simulations

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	3rd	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Electromagnetic field simulations	Lect	30	60	Elective	up to 240
b)	Electromagnetic field simulations	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

The lecture is centered around the Finite Integration Technique (FIT), a modern, efficient, and very successful simulation approach from the class of grid based methods. General electromagnetic field problems in domains with fairly arbitrary material distribution can be treated, including stationary fields, quasistatics, and waves. The modeling with FIT leads to algebraic matrix-vector equations, the solution of which will also be discussed. Furthermore, some alternative approaches such as Finite Differences and Finite Elements will be introduced. During the associated exercise, simple implementations in Matlab will be created. Students will be able to assess both the possibilities and the limitations of the discussed approaches for practical applications. Besides, the course provides the basis for extending the algorithms within scientific projects.

The lecture covers
- Introduction

- Motivation
- Classification of solutions
- Numerical Approaches

- Foundations of the Finite Integration Technique

- Lattice Maxwell Equations
- Properties of the discritization matrices
- Boundary conditions

- Solution to electromagnetic field problems

- Static fields
- Time variant fields
- Time harmonic fields (frequency domain)

Transient fields (time domain)

5 Learning outcomes and competences:

***Domain competence*:**

After attending the course, the student will be able,

- *to mathematically describe electromagnetic field problems of high complexity*
- *to implement simple numerical algorithms on a computer*
- *to physically interpret and visualize the results obtained numerically*

***Key qualifications*:**

The students

- *learn to transfer the acquired skills also to other disciplines*
- *extend their cooperation and team capabilities as well as the presentation skills in the context of solving the exercises*
- *learn strategies to acquire knowledge from literature and internet*
- *acquire a specialized foreign language competence*

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

7 Certified participation:

To	Form	Duration or length	Certified participation
			None

8 Requirements for participating in examinations:

None

9 Requirements for awarding credit points:

Credit points are awarded if the final module examination has been passed.

10 Weight for overall grade:

The module is weighted according to credit points (factor: 1).

11 Use of the module in other programs:

12 Module coordinator:

Prof. Dr. Jens Förstner

13 Further notes:

None

Fast Integrated Circuits for Wireline Communications

	Module group:	Workload (h):	CP:	Semester of study	Cycle:	Duration (in sem.):
	Specialization	180	6	3rd	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Fast integrated Circuits for Wireline Communications	Lect	30	60	Elective	up to 240
b)	Fast integrated Circuits for Wireline Communications	Exerc	30	60	Elective	up to 30

2 2 Options within the module

None

3 3 Admission requirements

Module "Schaltungstechnik" of the Bachelor Electrical Engineering or module "Circuit and System Design" of the Master "Electrical Systems Engineering" or comparable modules / lectures *Information: Unless otherwise specified, these are recommendations.*

4 4 Contents

The lecture deals with analysis and design of fast integrated electronic circuits for digital broadband communication systems. A part of the exercises will be performed using modern chip design CAD tools. The lecture is based on the compulsory lectures "Schaltungstechnik" rsp. "Circuit and System Design". The lecture deals with:

- Transmitter and receiver architectures for fiber-optic communications
- Transmitter and receiver architectures for chip-to-chip communications
- System design
- Semiconductor technology and integrated high-frequency devices
- Broadband amplifiers
- Current-mode logic
- Transmitter and receiver circuits
- PLLs for frequency synthesis and clock recovery
- Measurement methods

5 5 Learning outcomes and competences

Domain competence:

The student will be able to:

- describe and analyze transmitter and receiver architectures for broadband communication links
- understand and describe semiconductor technologies and integrated high-frequency devices for broadband circuits
- to analyze circuit design techniques for transmitter and receiver circuits and describe ways to optimize them
- to describe circuits in PLL technique for frequency synthesis and clock recovery
- to describe measurement methods

Key qualifications:

The students will learn how different interdisciplinary scientific domains and their methods - like mathematical signal and system analysis, non-linear and linear circuit analysis, semiconductor physics, semiconductor devices and high-frequency engineering - are applied together for the development of communications application.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

7 Certified participation:

To	Form	Duration or length	Certified participation
			none

8 Prerequisites for participation in examinations

None

9 Prerequisites for assigning credits

The credit points are awarded after the module examination (MAP) was passed.

10 10 Weighing for overall grade

The module is weighted according to the number of credits (factor 1).

11 Reuse in degree courses

EMA, WGMAET, CEMA, MA LABKET

12 Module coordinator

Prof. Dr.-Ing. Christoph Scheytt

13 Other notes

Implementation

Lecture with Exercises (including computer-aided design using electronic design software)

Teaching Material, Literature

Handouts and literature references will be given in the lecture.

Comments

As part of the lecture a 2-day excursion to IHP Leibnizinstitute for High-Performance Microelectronics in Frankfurt (Oder) is offered which includes the visit of a modern chip fabrication facility(participation in the excursion is voluntary).

Photonic Nanostructures

Photonische Nanostrukturen

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
Specialization	180	6	3rd	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Photonic Nanostructures	Lect	30	60	Elective	up to 240
b)	Photonic Nanostructures	Exerc	30	60	Elective	up to 30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

- Light-matter interaction (Maxwell's equations in matter, wave equation and Helmholtz equation, optical response of matter, polarization field, dielectric function of insulators, semiconductors and metals)
- Photonic nanostructures (one-dimensional periodicity: Bragg reflectors, transfer matrix algorithm; optical resonators I: micropillar resonators; optical resonators II: microdisk and ring resonators, electromagnetic fields in periodic media, symmetries and photonics, photonic crystal membranes; optical resonators III: defects in photonic crystals)
- Plasmonic nanostructures (surface and interface plasmon-polaritons, metallic nanoparticles, optical metamaterials)

5 Learning outcomes and competences:

The students are expected to be able to apply fundamental concepts of the interaction of light with nanostructures correctly to current problems of modern physics and to work out solutions for typical problems by themselves.

The students

- can recognize problems in the field of nanooptics by themselves and distinguish them from the optics of macroscopic objects,
- have the ability to describe and assess effects resulting from the interaction of light with dielectric and metallic nanostructures,
- can develop solutions to complex problems associated with optical nanostructures by themselves and argue their applicability based on the acquired knowledge,
- can, under guidance, develop and apply reasonable analytic and numerical approximation schemes for problems in nanophotonics,
- are able to deal with recent technical literature in English language on topics in nanooptics.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written examination or oral examination	120–180 min. 30–45 min.	100%

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<tr><td>11</td><td>Use of the module in other programs:</td></tr>
<tr><td></td><td>This module is also used in the master programs Physics as well as Chemistry.</td></tr>
<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Prof. Dr. Cedrik Meier, Prof. Dr. Thomas Zentgraf</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Lab courses

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
	180	6	1st-2nd	Each semester	2

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Lab courses	Lab	60	120	Compuls.	4 (2 groups in parallel)

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

Lab practicals in the subject area of Optoelectronics and Photonics. The students choose four subjects from a list announced in the electronic campus management system. Experiments on the following topics may be available: Ellipsometry and angle-resolved optical analysis, optical waveguide characterization, photon-pair sources based on parametric down-conversion, diode-laser-pumped solid-state laser with second-harmonic generation, optical length measurements, characterization of optoelectronic devices: LED laser, nonlinear optics on a computer, photodetectors, optical communications and high-frequency engineering, simulation of electromagnetic fields, modern lighting devices, correlation microscopy, etc.

5 Learning outcomes and competences:

The students are encouraged to learn independent experimental work by performing small research-related projects with well-defined tasks. In all experiments, a substantial focus is on independently designing proper set-ups and on performing the experimental work and analysis. This laboratory course prepares the students for their scientific work to be done within the modules lab project and master's thesis. The tasks are designed to go significantly beyond standard textbook topics and to include aspects of technical applications that are deemed relevant for future professional work in a R&D working environment.

The students

- learn how to perform experimental work on their own by executing small research-related projects with well-defined tasks,
- learn to use modern complex experimental equipment and methods in a real research-near environment within different working groups,
- acquire skills to study scientific literature written in English in preparation of the experiments to be performed and also for the documentation of the obtained results, which should be written in the style of a scientific publication,

are able to communicate scientific results in the context of current research.

6 Assessment:

[] Final module examination [X] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
		.	100%

The examination extends over four experiments. Each experiment comprises the preparation (including literature research), the actual execution (including feedback to comments given by the advisors), the written report (approx. 10 pages plus appendices, with literature review), a short presentation and an oral examination based on the

<table>
<tr><td></td><td>written report (approx. 15 min.). The overall grade is determined from the written reports (including presentations and oral examinations) of the four experiments with equal weights.</td></tr>
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<table>
<tr><th>To</th><th>Form</th><th>Duration or length</th><th>Certified participation</th></tr>
<tr><td></td><td></td><td></td><td>None</td></tr>
</table></td></tr>
<tr><td>8</td><td>Requirements for participating in examinations:</td></tr>
<tr><td></td><td>Attendance of the experiments is a requirement for participating in the examination.</td></tr>
<tr><td>9</td><td>Requirements for awarding credit points:</td></tr>
<tr><td></td><td>Credit points are awarded if the final module examination has been passed.</td></tr>
<tr><td>10</td><td>Weight for overall grade:</td></tr>
<tr><td></td><td>The module is weighted according to credit points (factor: 1).</td></tr>
<tr><td>11</td><td>Use of the module in other programs:</td></tr>
<tr><td></td><td>The module is also used in the master programs Physics and Materials Science.</td></tr>
<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Professors of Physics and Electrical Engineering Departments who are involved in the MSc Optoelectronics and Photonics.</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Topics in Optoelectronics and Photonics

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
	120	4	3rd	Winter semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Topics in Optoelectronics and Photonics	Sem	30	90	Compuls.	30

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

In the seminar, the students are taught to familiarize themselves with current topics of modern optoelectronics and photonics, to accumulate relevant information and finally to present their knowledge to the other students in the framework of the seminar. This opportunity to deliver their own presentations is intended to enhance the students' expertise with respect to current research topics as well their personal presentation skills. Topics may include: heterodyne interferometer, white-light interferometry, parametric amplification, interferometric length measurement, optical increment encoder, Rubidium atomic clock, optical frequency combs, STED mikroscopy, Erbium doped fiber amplifiers, mono mode semiconductor laser, femto second laser, FRET energy transfer, single-photon sources, generation of entangled photon pairs, Hong-Ou-Mandel effect, holography, modern solar cells, THz spectroscopy, optical coherent tomography, SHG microscopy, optical gas sensors, Raman-spectroscopy, material processing with lasers, photon number resolving photo detectors, CCD sensors, streak cameras

5 Learning outcomes and competences:

The students

- can familiarize themselves with a given topic of modern photonics on their own and accumulate relevant information by means of individual study and literature research,
- are able to recognize and explain relations between the topic and neighboring fields,
- can design their presentation under pedagogical and disciplinary aspects,

make use of the acquired experience in order to enhance their personal presentation skills as well as their communication skills when answering scientific questions.

6 Assessment:

[] Final module examination [X] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written report followed by a presentation	Ca. 10 pages and ca. 25 min	100%

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

<table>
<tr><td>7</td><td>Certified participation:
<table>
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<tr><td></td><td></td><td></td><td>None</td></tr>
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</td></tr>
<tr><td>8</td><td>Requirements for participating in examinations:</td></tr>
<tr><td></td><td></td></tr>
<tr><td>9</td><td>Requirements for awarding credit points:</td></tr>
<tr><td></td><td>Credit points are awarded if the final module examination has been passed.</td></tr>
<tr><td>10</td><td>Weight for overall grade:</td></tr>
<tr><td></td><td>The module is weighted according to credit points (factor: 1).</td></tr>
<tr><td>11</td><td>Use of the module in other programs:</td></tr>
<tr><td></td><td></td></tr>
<tr><td>12</td><td>Module coordinator:</td></tr>
<tr><td></td><td>Professors of Physics and Electrical Engineering Departments who are involved in the MSc Optoelectronics and Photonics.</td></tr>
<tr><td>13</td><td>Further notes:</td></tr>
<tr><td></td><td>None</td></tr>
</table>

Lab Project

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
	420	14	3rd	Each semester	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Lab Project	Di-verse	7,5	412	Compuls.	1

2 Options within the module:

None

3 Requirements for admission:

None

4 Contents:

Supervised work on small research project on a specific subject.

5 Learning outcomes and competences:

The Lab Project constitutes a first, individual research task on a specific subject with a scientific or engineering focus. The students will acquire the ability to solve a complex task in a supervised setting. Besides learning to work independently, they will also acquire the required organizational skills. They will be able to communicate their research task, discuss the selected methods and approaches, and present their results in a written seminar paper. After completion, the students will possess extended knowledge in the subject area of their project and its potential technological applications.

6 Assessment:

[X] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Seminar paper	ca. 30 min	100%

7 Certified participation:

To	Form	Duration or length	Certified participation
			None

8 Requirements for participating in examinations:

9 Requirements for awarding credit points:

Credit points are awarded if the final module examination has been passed.

10 Weight for overall grade:

The module is weighted according to credit points (factor: 1).

11 Use of the module in other programs:

12	**Module coordinator:**
	Professors of Physics and Electrical Engineering Departments who are involved in the MSc Optoelectronics and Photonics.
13	**Further notes:**
	None

General Studies

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
	180	6	1st-2nd	Each semester	2

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	General Studies	Var-ies	60	120	Elective	Varies

2 Options within the module:

Can be chosen from the modules offered at the University as published in the electronic campus management system.

3 Requirements for admission:

None

4 Contents:

Students may choose freely from all modules offered at the University. However, it is recommended that students with limited or no proficiency in German devote part of their studies to acquire German language skills.

5 Learning outcomes and competences:

In their general studies, students will acquire key skills (e.g., foreign language skills, project management skills, writing skills, …) and may acquire knowledge and a deeper understanding for subjects outside their own discipline.

6 Assessment:

[] Final module examination [] Module examination [] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	none	.	

7 Certified participation:

To	Form	Duration or length	Certified participation
	Certified participation as required by the course chosen (e.g., Report, Seminar paper, oral presentation, …)		Certified participation

Confirmation of how the assessment is to be performed shall be given at the latest in the third week from the start of teaching by the teacher concerned.

8 Requirements for participating in examinations:

9 Requirements for awarding credit points:

Credit points are awarded when the certified participation was obtained.

10 Weight for overall grade:

The module is weighted according to credit points (factor: 1).

11 Use of the module in other programs:

12	**Module coordinator:**
	Varies.
13	**Further notes:**
	None

Master thesis

Module group:	Workload (h):	CP:	Semester of study:	Cycle:	Duration (in sem.):
	900	30	4th	Summer term	1

1 Module structure:

	Course	Type	Contact time (h)	Self-study (h)	Status (C/E)	Group size (students)
a)	Written master thesis				Compuls.	1
b)	Oral defense				Compuls.	1

2 Options within the module:

None

3 Requirements for admission:

Successfully completed lab project and at least 74 credit points already obtained, in case of conditional enrolment, proof that the relevant examinations have been passed.

4 Contents:

Independent work on a research project under individual guidance, detailed presentation of the problem and the obtained results and discussion of their relevance in the context of current research in the master's thesis, oral presentation and defense.

5 Learning outcomes and competences:

The students

- can familiarize themselves independently with a research topic,
- are able to research the international scientific literature with regard to the given topic and get an overview on the current state of research,
- have the ability to familiarize themselves with a complex measurement technique or a complex theoretical concept and can pursue their own research project adhering to scientific methods and standards,
- can work together in a research team,
- can write a scientific thesis independently,
- can structure a scientific presentation about their own results appropriately and present it to an audience with contextual information about the current state of research,
- have learned to also handle critical questions in a scientific discussion and to argue their own point of view,
- know the rules of good scientific practice and adhere to these,
- are able to develop a realistic timetable for their own complex project,
- possess qualifications like self-dependence and the ability to work in a team

6 Assessment:

[] Final module examination [] Module examination [X] Partial module examinations

To	Form of assessment	Duration or length	Weights for module grade
	Written master's thesis		5/6
	Oral defense incl. examination	30-45 min.	1/6

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